OPEN ACCESS

University of BRISTOL

De Carli, P., Costantini, I., Sessa, P., Visentin, S., Pearson, R. M., & Simonelli, A. (2019). The expectant social mind: A systematic review of face processing during pregnancy and the effect of depression and anxiety. *Neuroscience and Biobehavioral Reviews*, *102*, 153-171. https://doi.org/10.1016/j.neubiorev.2019.04.013

Peer reviewed version

License (if available):
CC BY-NC-ND

Link to published version (if available):
10.1016/j.neubiorev.2019.04.013

Link to publication record in Explore Bristol Research
PDF-document

This is the author accepted manuscript (AAM). The final published version (version of record) is available online via Elsevier at https://www.sciencedirect.com/science/article/abs/pii/S014976341830900X?via%3Dihub . Please refer to any applicable terms of use of the publisher.

University of Bristol - Explore Bristol Research
General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:
http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/

The expectant social mind:

A systematic review of face processing during pregnancy and the effect of depression and anxiety

Pietro De Carli[a]*, Ilaria Costantini[a,b], Paola Sessa[a,c], Silvia Visentin[d],

Rebecca M Pearson[b], Alessandra Simonelli[a]

[a] Department of Developmental and Social Psychology, University of Padua
Via Venezia,8 35131 Padova (PD), Italy

[b] Centre for Academic Mental Health, Population Health Sciences, Bristol Medical School, University of Bristol, Oakfield House, Oakfield Grove, Bristol BS14 8TF, United Kingdom

[c] Padova Neuroscience Center, University of Padua, Padua, Via Venezia,8 35131 Padova (PD), Italy

[d] Department of Woman and Child's Health, University of Padua, Via Giustiniani, 3 - 35128 Padova (PD), Italy

*Correspondence concerning this article should be addressed to:

Pietro De Carli
Department of Developmental and Social Psychology, University of Padua
Via Venezia,8 35131 Padova (PD), Italy
pietro.decarli@gmail.com
pietro.decarli@unipd.it
Tel. (+39) 049-8271282
Fax: (+39) 0498276511

Ilaria Costantini, ilaria.costantini@bristol.ac.uk
Paola Sessa, paola.sessa@unipd.it
Silvia Visentin, visentin78@gmail.com
Rebecca M Pearson, rebecca.pearson@bristol.ac.uk
Alessandra Simonelli, alessandra.simonelli@unipd.it

The authors report no conflicts of interest.

No specific funding sources supported this publication.

Abstract

Pregnancy carries enormous changes in the psychological and neurophysiological domains. It has been suggested that pregnant women undergo a cognitive reorganization aimed at increasing the salience of social stimuli (i.e., the tendency of social cues to capture observer's attention, so that their processing results prioritized). The goal of the present work was to systematically review the empirical evidence of a change in face processing during pregnancy. Moreover, we explored whether face processing is associated with antenatal depression and anxiety and the extent to which this is part of a potential mechanism to explain detrimental effects of maternal psychopathology on infant outcomes. We identified 19 relevant studies and discussed them based on their methodological qualities. The results of the review suggest that even though it is not possible to draw firm conclusions, pregnancy is likely to be a plasticity window for face processing at the behavioral and neural levels. Evidence confirms the detrimental effect of depression and anxiety on face processing during pregnancy. Clinical implications for parenting interventions are discussed.

Keywords: pregnancy; brain plasticity; face processing; anxiety; depression; parenting.

1. Introduction

Pregnancy plays a specific and fundamental role in human reproduction and ultimately in ongoing human survival. Because birth is highly dependent on the success of pregnancy, it is not surprising that evolution has specifically shaped this complex process as few others have been in human life. In fact, pregnancy produces massive changes in women's physical, physiological and psychological functioning to promote their survival and that of fetuses. New tasks and duties are required by pregnant women. With regards to metabolism, the new situational demand consists of resetting women's nutritional uptake to provide fetuses with energy, protecting them from exposure to maternal stress and storing a mother's energy for future lactation. Similarly, at a behavioral level, two of the most important aims consist of protecting a fetus from current danger and preparation for a future role as a mother. In fact, a fetus is particularly vulnerable during pregnancy, especially during the first months of gestation, when the risk of miscarriage is at its highest. Protection from danger is essential to promote survival. Pregnant women consistently perceive situations as riskier compared to nonpregnant controls and engage in less risky behaviors (Crawley et al., 2008). Moreover, infants are highly dependent on parents' resources after birth, and new mothers are asked to engage in tasks that require new abilities, especially in understanding infants' signals and needs. In fact, mothers have an augmented sensitivity toward infant stimuli compared to nulliparous females both at behavioral (Lehmann et al., 2013) and neural (Seifritz et al., 2003) levels.

Due to the high relevance of fulfilling these aims for survival, evolution is likely to have contributed to shaping adaptive pregnancy processes. At a cognitive level, women often report memory deficits during pregnancy (Brindle et al., 1991). Empirical evidence indeed supports the onset of mild memory deficit (Henry and Rendell, 2007) within a slight and temporary general cognitive impairment (Anderson and Rutherford, 2012), likely due to the increased stress perceived during pregnancy (Dunkel Schetter, 2011). Recently, it has been suggested that these mild memory deficits could be part of a larger cognitive reorganization that would lead to benefits, especially in the social cognition domain. Anderson and Rutherford (2012) proposed that, consistent with an

adaptationist perspective, an augmented sensitivity to social stimuli would allow a better and faster identification of potential threats and consequently increase women's ability to protect themselves and their fetuses. In particular, the most powerful way to access social information is face processing, especially emotions expressed facially. In other words, allocating more resources to detecting, for instance, fearful emotional expressions allows better and quicker response to potential danger in the environment (Schutter et al., 2008). Interestingly, the same process, an augmented salience toward social cues, is also crucial to aiding the transition to motherhood and the essential ability to perceive and understand infants' signals to provide the care and support infants need (Stein et al., 2010). It is therefore possible that an increased investment in processing social stimuli could favor fetus protection and future ability to support infant adaptation and development.

The hypothesis that pregnancy is a potential plasticity window for the salience of social stimuli, especially faces, is particularly relevant for considering how pregnancy may impact upon mother's mental health (Paschetta et al., 2014) which in turn impact upon a child's development and outcomes (Stein et al., 2014). In particular, antenatal depression and anxiety seem to have a long-term detrimental effect on children's mental health (Pearson et al., 2013a), but the mechanisms of this association are far from understood. Because individual differences in parental sensitivity (i.e., the ability to respond to infant needs adequately and contingently) rely on various processing of infant stimuli (Musser et al., 2012), a possible association of depression and anxiety with the salience of social stimuli during pregnancy may be considered. If found, then the results would be consistent with the idea that the quality of face processing during pregnancy could play a potential role in the complex association between perinatal psychopathology and future negative outcomes (Stein et al., 2014).

Some studies have tested these hypotheses, but research is disparate and an attempt to summarize available evidence is lacking. To fill this gap, the present review is aimed at examining the literature regarding the role of pregnancy in a specific domain of social cognition (i.e., face processing). In particular, we are interested in studies that considered the salience of adult and

infant faces during pregnancy (or just after pregnancy) to explore whether pregnancy is indeed a plasticity window for this ability. We focused our inquiry on faces because they are unique among social stimuli in conveying information about the identity and status of individuals around us. The brain is highly specialized in processing human faces in light of their enormous emotional salience, in particular when related to potential threats such as faces with fearful expressions (Hariri et al., 2003). In addition, face processing is primarily involved in social communication (Haxby et al., 2002). Therefore, it is possible that during a period of high vulnerability such as pregnancy, resources are coopted to better analyze and understand facial cues to detect even subtle signs of potential danger and foster others' help. Furthermore, a pregnant woman's future role as a mother is highly dependent on the ability to read an infant's signals, especially facial expressions. Therefore, an augmented salience for adult faces could be fruitfully extended to infant faces. Finally, the effect of antenatal depression and anxiety was reviewed to explore whether face processing could be a candidate mechanism contributing to linking maternal depression and anxiety to difficulties in responding to infants (which is largely dependent on facial cues) and ultimately has a potentially negative impact on children's developmental trajectories.

1.1. Animal studies and neurophysiological evidence

The mammalian brain developed within the context of transitioning from reptilian "egg dropper" to mammalian "nest builder." Maternal behavior has thus developed as a powerful vehicle for updated information transfer from generation to generation, and adaptations to meet this demand are of clear evolutionary advantage. Animal models consistently show that motherhood represents a "boost" (Kinsley et al., 2015; Macbeth and Luine, 2010) for females to adapt to the new environmental demands. In particular, females rats before motherhood actively avoid pup signals, while during pregnancy and lactation they become attracted to pups and care for and protect them (Fleming and Luebke, 1981; Numan, 2007). Moreover, motherhood is clearly associated with improvement in reference memory, spatial learning, foraging, and boldness (Kinsley et al., 2015).

Importantly, these changes are long lasting and rely on many different brain modifications at morphology and molecular levels (Brunton & Russell, 2008; Kinsley et al., 2015). Kinsley and colleagues (2015, 1999) showed the fundamental role of offspring in providing an enriched environment for women. For instance, Bridges and colleagues (1996) showed that even during pregnancy late term fetuses can stimulate maternal behaviors by releasing placental lactogens. Therefore, through biological mechanisms in addition to behavioral ones, infants provide stimuli to increase maternal care toward them and boost maternal cognition. It is likely that the perception of social stimuli such as faces and infant sounds changes with pregnancy and motherhood. No animal study has focused on the processing of these kinds of stimuli, but evidence suggests that they could be involved in the drastic behavioral changes across pregnancy. For instance, if rats are exposed to a novel environment, then only postpartum rats (compared to nonparents) will prefer the novel environment associated with pups (Fleming et al., 1994). Finally, the alterations in hormones associated with social cognition, such as oxytocin (Shamay-Tsoory and Abu-Akel, 2015), are consistent with the hypothesis of an augmented sensitivity to social cues.

In humans, very few studies have focused on brain alterations due to motherhood and especially pregnancy, but a recent study by Hoekzema et al. (2016) proposed a well-structured and innovative design to address this issue. MRI morphological data were obtained from 20 nulliparous women enlisted in a fertility center before and after pregnancy. Interestingly, the overall brain analyses reported gray matter reductions (i.e., better functionality) primarily in the anterior and posterior midline, the lateral prefrontal cortex bilaterally and the temporal cortex bilaterally. Following a bottom-up approach, the authors noticed that these areas were substantially similar to the ones involved in theory of mind as reported by a meta-analysis (Schurz et al., 2014). Moreover, the volume change in these areas was associated with the quality of the mother-child relationship after birth measured with a questionnaire about mother-child attachment. These changes lasted two years after birth, and the same areas were significantly activated while mothers viewed pictures of their infants. Finally, the results of these studies are consistent with the hypothesis of changes in

social cognition abilities during pregnancy associated with augmented sensitivity to social stimuli, even if no analyses of brain functionality in response to an infant's face were presented per se.

1.2. Infant faces processing

Soon after a child's birth, a brand new set of behaviors will be asked of the new mother because she will be responsible for the infant's care, protection and security (Ainsworth et al., 1974; Bowlby, 1969). Parents' ability to recognize and respond to these signals properly is crucial for healthy infant development (Ainsworth et al., 1974; Bowlby, 1969; De Carli et al., 2018, 2017). From an evolutionary standpoint, protecting and providing offspring with enough resources to reach adult age and reproduction is at least as important as reproductive behavior per se. The high dependency of the fetus and the newborn on the behavior of adults implies that mothers would adaptively show an augmented sensitivity to infants' cues (e.g. to identify children's needs) and to environmental signals (e.g. to protect children from possible dangers). Mothers indeed show specific brain responses to infant stimuli (compared to nonmothers; Proverbio et al., 2006). On one hand, this effect is at least partially due to an experiential change, because, for instance, the duration of motherhood is associated with increasing effects on mothers' neural processing of infant vocal cues (Parsons et al., 2017) and brain activation during the perception of infants' faces is susceptible to the quality of birth experience and infants' characteristics (Montirosso et al., 2017). On the other hand, it is possible that pregnancy and more generally preparation for parenthood are also responsible for a change in the perception of infant stimuli (e.g., faces) to prepare expectant women for the caregiving task. It would make evolutionary sense that a mother is adapted to respond to infant stimuli from the earliest moments of birth. A set of studies seems to provide indirect evidence consistent with this hypothesis. First, the previously mentioned study on the long-lasting brain structure modifications due to pregnancy found that these changes predicted the quality of mother-child attachment subjectively reported by women (Hoekzema et al., 2016). This means that pregnancy-related changes are probably highly adaptive in improving women's caregiving abilities

and can be considered an evolutionary advantage. Because maternal sensitivity is associated with mothers' awareness of subtle differences in infants' expressions (Donovan et al., 2007), it is possible that one of the mechanisms implicated in the association between brain structure and mother-child relationship is a change in face perception. Second, face perception is susceptible to endocrine changes, such as oxytocin administration (Shamay-Tsoory and Abu-Akel, 2015). Even if the effects of oxytocin on the perceptions of infant stimuli appear complex and lack consistency across studies (Marsh et al., 2012; Riem et al., 2017a, 2014), it seems plausible that the massive endocrine changes of pregnancy can alter the perception of highly salient social cues such as infant faces (Shamay-Tsoory and Abu-Akel, 2015). Hormone changes during pregnancy are consistently associated with postpartum parenting outcomes (Edelstein et al., 2017). In addition to infant faces, a series of studies found that newborn infants' odors are considered more pleasant by new mothers in the very early postpartum stage (Fleming et al., 1993). In fact, this period is associated with changes in heart rate and glucocorticoids that sustain mothers' nurturing responses to infant odors or infants crying (Stallings et al., 2001).

In light of all these considerations, the present review will consider infant faces as a specific target of investigation given the high relevance of this stimulus for pregnant and early postpartum women.

1.3. Antenatal depression and anxiety

Antenatal depression and anxiety are major public health issues worldwide (Stewart, 2011). Prevalence varies in the studies, but it is estimated to be from 7% to 20 % in high-income countries (Andersson et al., 2003; Gavin et al., 2005; Lee et al., 2007). In addition, depression shows higher prevalence in pregnant women compared to non-pregnant controls (Ashley et al., 2016). Antenatal depression and anxiety are known to constitute both risks for later negative outcomes in children and a specific predictor of child development, even controlling for postpartum depression (O'Connor et al., 2002; Pearson et al., 2013a). Despite the studies on the long-term effects of

antenatal maternal depression and anxiety that documented a higher risk of depression in 18-year-old offspring (Pearson et al., 2013a), the explanations for this association remain partially unknown. Two possible mechanisms have been proposed so far. One relies on fetal programming (Kapoor et al., 2006), because the fetus is exposed to stress hormones such as cortisol (O'Donnell et al., 2009) through the placenta, especially in cases of maternal depression. Higher cortisol exposure during pregnancy could lead to negative outcomes in later development. The second mechanism relies on the known association between antenatal anxiety and depression and a lower quality of maternal sensitivity after birth (Edwards and Hans, 2016) and in turn a negative long-term outcome for a child (Raby et al., 2015). Moreover, maternal sensitivity is associated with the perception of infants' signals and emotional cues (Leerkes, 2010; Musser et al., 2012). It is possible that during pregnancy, in light of the hypothesized plasticity for the perception of social cues, women are particularly prone to the effects of depression and anxiety on the perception of infant cues. Antenatal anxiety and depression could interfere with the normal process of cognitive reorganization due to pregnancy and therefore lead to worse maternal sensitivity in the postpartum period.

One of the aims of the present study is to review all the studies that have explored the effect of anxiety and depression in altering the face processing during pregnancy to test the hypothesis of a heightened vulnerability in pregnant women's social cognition. Due to the disruptive effects of antenatal anxiety and depression on children's development, it is highly relevant to understand which processes cause maladaptive outcomes to design specific interventions.

1.4. The present study

In sum, the main aim of the present study is to provide a systematic review of all the studies investigating face processing in women during pregnancy. Behavioral and neurophysiological measures were considered. We were specifically interested in two kinds of studies depending on the two aims. First, we reviewed studies that tested whether face processing abilities change during

pregnancy and whether the changes are possibly driven by endocrine modifications. Second, we reviewed those studies that investigated the effect of anxiety and depression in face processing during pregnancy. Understanding the effects of clinical variables such as anxiety and depression is particularly relevant because they are most likely to represent risk factors for the wellbeing of mothers and children's development.

2. Methods

A computer-based literature search was conducted in four main databases: PubMed, Psychinfo, Scopus, and Web of Science. The title/abstract search string was ("pregnancy" OR "pregnant") AND ("cognitive" OR "cognition" OR "emotion" OR "face processing" OR "face perception" OR "social").

Figure 1 shows the flow chart of the systematic review, and it highlights the step-by-step criteria for the screening and the record count (excluded and included results at each step). Records were considered eligible if they were already published or available online. No previous reviews, theoretical pieces, qualitative searches, English articles, viewpoints, letters, or dissertations were included. Because we were specifically interested in the effects of pregnancy, we considered studies that reported measures of social cognition in pregnant women or in the very early postpartum stage (within 1 week from birth). A total of 19 studies were included in the present review. Results are presented into two separate tables, depending on the two aims of the present study. Table A presents the studies that address the issue of whether pregnancy alters social cognition. Table B shows the studies investigating individual differences in social cognition during pregnancy associated with anxiety or depression.

3. Results

3.1. Description of the results depending on the main aims of the study

Eight studies (presented in Table A) addressed the issue of a possible modification in social cognition abilities during pregnancy. These studies employed different methodologies and designs including cross-sectional studies (i.e., pregnant vs. nonpregnant women), longitudinal studies within pregnancy (i.e., pregnant women assessed at different times during pregnancy), or longitudinal studies during and after pregnancy (i.e., women assessed during pregnancy and after child birth). In particular, four studies combined the cross-sectional and longitudinal methodologies (Cobey et al., 2015; Gingnell et al., 2015; Roos et al., 2012, 2011). One study used an early/late pregnancy within-subjects design (Pearson et al., 2012a). However, the authors did not compare results between early and late pregnancy, therefore the study was excluded from Table A, but it is presented in Table B because data also relate to anxiety and depression. One study presented a randomized clinical trial to assess the effect of cognitive behavioral therapy (CBT) on the attentional bias toward faces in a sample of depressed women (Pearson et al., 2013b). Because the nondepressed control group was assessed only during early pregnancy and the depressed group received an intervention (CBT or treatment as usual), no inferences can be made on the exact role of pregnancy in social cognition. Therefore, this study is presented in Table B. None of the considered studies assessed women before pregnancy.

Sixteen studies (11 presented in Table B and five presented in Table A) addressed the issue of possible individual differences in social cognition associated with anxiety or depression during pregnancy. All of these studies implied a measure of anxiety or depression during pregnancy and a task with social stimuli during pregnancy or during and after pregnancy. Five studies presented in Table A also report measurements of anxiety or depression. Even though they are not reported in Table B, for the sake of brevity they inform the association between face processing and depression and/or anxiety (Gingnell et al., 2015; Pearson et al., 2009; Raz, 2014; Roos et al., 2012, 2011).

Three studies also measured postpartum mother-child relationships or child development to test whether the variability in social cognition during pregnancy can predict later outcomes (Bernstein et al., 2014; Leerkes, 2010; Pearson et al., 2011). Finally, 10 studies considered both anxiety and depression, but only two of them (Gil et al., 2011; Rutherford et al., 2017) tested the specific contribution of anxiety and depression on face processing.

3.2.Study designs

Seven studies used a pregnant women/control women design. This allows testing the role of pregnancy functioning, but with less power than a longitudinal design because it cannot rule out a possible role of preexisting differences between groups. A critical issue is the selection of the control group. Various studies proposed different strategies. Anderson and Rutherford (2011) matched the control and the pregnant groups on IQ, household income, relationship status, age and motherhood, whereas Cobey et al. (2015) only considered groups of comparable age. Roos and colleagues (2012) selected a control group of comparable age and controlled in the analysis for education levels because there were differences between the control and pregnant groups of women. Roos et al. (2011) selected the control group matching for educational levels and age. Raz (2014) matched the control group for age, ethnicity, educational level, number of children and level of anxiety. Because the effect of the menstrual cycle in processing social stimuli is known (Derntl et al., 2008; Guapo et al., 2009), two studies controlled for the stage of menstrual cycle using different strategies. Jones and colleagues (2005) recruited a nonpregnant sample selected to represent each phase of the entire menstrual cycle, with none of the participants having reported a nonregular cycle or using hormonal contraceptives. In addition, all participants were heterosexual, and controls were matched in terms of age, partnership, and country of residence. Gingnell et al. (2015) selected naturally cycling control subjects matched for age, number of pregnancies, body mass index and university education. To ensure a better comparison between controls and women in the early and late postpartum stages based on progesterone levels (Sundström Poromaa and Gingnell, 2014), the

authors collected data in two sessions. Control women were assessed during the late luteal phase of the menstrual cycle (postovulatory days 8-13, to be compared with early postpartum stage) and in the midfollicular phase (6-12 days postmenstrual bleeding, to be compared with late postpartum stage).

Ten studies implied a longitudinal design, with high variability across the studies. Pearson et al. (2013b, 2009) assessed differences between early and late pregnancy. Pearson et al. (2012a) also assessed the same task in the same time windows, but they did not test differences between early and late pregnancy. Roos and colleagues (2012, 2011) assessed the same tasks during the second and third trimesters of pregnancy. Five longitudinal studies presented postpartum assessments. Cobey et al. (2015) and Leerkes (2010) repeated the same task during and after pregnancy. Three studies added postpartum outcome measures: Pearson et al. (2011) measured the quality of mother-child relationship at 6 months after birth; Bernstein et al. (2014) measured infant attachment disorganization at 18 months after birth; and Leerkes (2010) measured maternal sensitivity 6 months after birth. Finally, Gingnell et al. (Gingnell et al., 2015) assessed the same fMRI task both 48 h and between 4-6 weeks after birth.

The remaining five studies focused on a single time point and tested the associations with anxiety and depression using no control groups. Pearson et al. (2010), Macrae et al. (2015) and Murphy et al. (2015) assessed pregnant women between the 11th and the 18th week gestational age, whereas Rutherford et al. (2017) considered the last trimester of gestation, or more specifically between the 34th and the 38th week of gestational age. Finally, Gil et al. (2011) tested women 3 days after delivery.

3.3. Participants

The studies included in the present systematic review are characterized by substantial variability in sample sizes, ranging from 19 to 972. Due to the high differences in study designs,

measures and statistical analyses, it is difficult to compare the studies depending on sample size and power.

In 17 out of 19 studies, pregnant women were tested, whereas in two studies the sample of participants included women in the very early postpartum stage (Gil et al., 2011; Gingnell et al., 2015). In 17 out of 19 studies, women were recruited from community samples, whereas in two studies different high risk groups were selected. Bernstein et al. (2014) recruited women with high risk for depression or problematic parenting. Moreover, using an extreme-group design, only children who showed secure or disorganized attachment at 18 months were selected. Pearson et al. (2013b) used a three-question depression-screening questionnaire to select the depressed group for the intervention. Women were enrolled in the study if their depression was confirmed by ICD-10 criteria based on a follow-up clinical interview.

Besides pregnant or postpartum women, two studies presented data of infant-mother relationships at 3-6 months (Pearson et al., 2011) or at 6 months (Leerkes, 2011) after birth. One measured an observed outcome in children at 18 months (i.e., attachment; (Bernstein et al., 2014).

Because evidence suggests differences in social cognition abilities on the basis of the time in which this was tested during pregnancy (Pearson et al., 2009), participants' gestational age at assessment could be relevant. Beside the two studies limited to the postpartum stage (Gil et al., 2011; Gingnell et al., 2015), only two studies (Anderson and Rutherford, 2011; Jones et al., 2005) recruited women all across stages of pregnancy without taking gestational age into account. Roos et al. (Roos et al., 2011) longitudinally followed the pregnant group, assessing the women at each trimester of pregnancy. Pearson et al. (Pearson et al., 2013b, 2012b, 2009) recruited pregnant women in the first/second trimester (range about 7-14 weeks of gestation) and assessed them again in the third trimester (33-39). Roos et al. (2012) tested within-subjects differences between the second and the third trimester. Three studies (Macrae et al., 2015; Murphy et al., 2015; Pearson et al., 2010) focused on women at the end of the first trimester or during the second trimester. Two studies (Cobey et al., 2015; Raz, 2014) recruited women during the second and the third trimester.

Finally, five studies focused on the third trimester only (Bernstein et al., 2014; Leerkes, 2010; Pearson et al., 2011; Rutherford et al., 2017, 2016).

Animal (Kinsley et al., 2015) and human (Hoekzema et al., 2016) studies agree on the long-term nature of the changes in cognition due to motherhood. Parsons and colleagues (Parsons et al., 2017) recently found that neural processing of infant vocal cues depends on duration of motherhood. Therefore, it is essential to consider whether pregnant women and controls are already mothers because this could alter the processing of social stimuli, in particular infant signals. Six studies did not report data on parity. Gingnell et al. (2015) did not report data on parity characteristics of the sample, but the control group was selected between nulliparous or women who gave birth at least one year before. Four studies reported the primiparous and multiparous frequency in the sample (Anderson and Rutherford, 2011; Pearson et al., 2013b, 2011; Rutherford et al., 2017). Four studies (Macrae et al., 2015; Pearson et al., 2012a, 2010, 2009) controlled for parity in the analyses. Raz (2014) matched the pregnant/control groups for number of children. Cobey (2015) selected only nulliparous women for the control group. Bernstein et al. (2014), Murphy et al. (2015) and Leerkes (2010) recruited only primiparous women.

This variability is of course a great limitation to considering whether pregnancy plays a specific role in face processing. More specifically, in studies where groups were matched for parity or parity was controlled in the analysis, it is, however, possible that the real effect of pregnancy was underestimated or overestimated. Finally, no study addressed the question of a pregnancy-specific effect, considering at least three groups: pregnant primiparous, nonpregnant primiparous and nulliparous control women.

3.4. Social stimuli

All the studies included in the present review used faces as stimuli. One study presented infant faces concurrently with infant cries (Pearson et al., 2012a), and one showed a video of infant faces while crying (Murphy et al., 2015).

Nine studies presented only adult faces. Notably, all the studies that addressed the issue of whether pregnancy alters social cognition have employed only adult faces as stimuli. Eight studies used only infant faces, whereas three studies (Gil et al., 2011; Pearson et al., 2010; Rutherford et al., 2017) considered both infant and adult faces. Sixteen studies involved emotional faces.

3.5. Tasks

Wide variability of task types implemented in the various studies was also observed. Even though all the tasks presented human faces as stimuli, they differed with regard to procedures, aims and dependent variables measured. For the sake of clarity, we organized the tasks into six categories. To note, in some studies more than one task was implemented, and in a few cases the same task can also be classified within more than one category. Therefore some studies can be found more than once.

1. *Emotion recognition*. Four studies reported participants' accuracy in interpreting emotional expressions. Pearson et al. (Pearson et al., 2009) used a task from a battery of standardized measures of social competence (SASI, Skuse, 2005). Different adult emotional expressions were presented to participants who were asked to choose which emotion was displayed from six options. An accuracy score was generated for each emotion: happiness, sadness, fear, anger, disgust and surprise. During an fMRI session, Gingnell et al. (Gingnell et al., 2015) used a paradigm to compare processing of emotional expressions (angry and fearful adult expressions) and processing of simple geometric figures (lines and shapes; Shin and Liberzon, 2010). Participants were instructed to select one of two images (presented below the target) displaying the same emotion or orientation as the target. Accuracy and reaction times were recorded. Bernstein et al. (2014) administered the IFEEL Picture System (Emde et al., 1987). Some pictures of 12-month-old infants' facial emotional were presented, and participants were asked to write on a paper sheet how they would describe the emotions on the screen. Their responses were coded as belonging to one of 12 distinct emotion categories

and then reduced to three categories: positive, negative and "other." Two kinds of scores were obtained: the frequency of each emotion category and the level of agreement with a reference sample. Leerkes (2010) assessed maternal difficulties in encoding infants' distress. Mothers had to rate on a 7-point scale (ranging from 1 = high positive to 7 = high negative) infant distress; pregnant women were asked to identify an infant's main emotion for each clip. A score was computed by summing (1) the number of times the distress was downgraded in respect to experts' evaluations and (2) the number of times a nonemotional word or a positive word was used to describe infant distress.

2. *Attentional bias toward emotional faces*. Six studies investigated the attentional bias toward faces by means of reaction times. Three studies (Pearson et al., 2013b, 2011, 2010) used the same task with the same stimuli. Participants were instructed to fixate on a central cross on a computer screen behind which facial stimuli (distressed or nondistressed infants) were presented. Two lines were presented at the periphery of the screen, a horizontal one and a vertical one. Participants had to indicate on which side of the screen the vertical line had appeared by pressing a response key. Two scores of attention disengagement from the central to the peripheral stimulus were computed, depending on the facial expression behind the cross. Roos et al. (Roos et al., 2012, 2011) measured the selective attention to threat (i.e., emotional faces compared to neutral faces) by means of a Facial Stroop Task. Emotional or neutral faces were presented on the screen and participants were required to name the color in which the faces or masks appeared (red, green or blue). In both studies (Roos et al., 2012, 2011), facial stimuli were above threshold for conscious perception (stimulus presentation of 298 ms), whereas in Roos et al. (2011) a second version of the task (Masked Stroop) was implemented with facial stimuli below threshold for conscious perception (stimulus presentation of 2 ms). In Roos et al. (2012), angry and happy faces were also presented. Attention bias scores were determined by subtracting color-naming times on neutral faces from color-naming times for fearful faces. Raz (Raz, 2014) used a visual emotional oddball

task during EEG/ERP recording, including faces and shapes. Facial expressions were neutral (nontarget) or angry (target). Geometric shapes were empty (nontarget) or with a black cross in the middle (target). Participants were instructed to press the space bar when a target stimulus appeared on the screen. Reaction times and error rate were recorded (omission rate and commission rate).

3. *Preferences for faces*. Cobey et al. (2015) manipulated pictures of adults to obtain a masculine and a feminine version of the same face. Participants were asked to choose which one was the "most attractive." Jones et al. (2005) created a "healthy" and an "unhealthy" version of each adult face. The couple of faces were shown to participants, who were asked to choose which one they preferred and to express the strength of the preference from "guess" to "strong preference."
4. *Evaluation of faces*. Macrae et al. (2015) showed participants distressed, neutral and happy infant faces. Each face was presented three times in random order. Below each picture, one of three Likert scales (1 to 8) was presented: "I want to comfort," "I want to turn away" and "I feel anxious." Gil and colleagues (2011) asked participants to rate facial expressions of adults and infants displaying anger, happiness, sadness and neutrality. Each picture was rated on the aforementioned emotions plus disgust, by means of a series of 7-point scales.
5. *Memory of faces*. Only one study (Anderson and Rutherford, 2011) focused on participants' ability to recognize faces previously presented. The training session of the memory task was disguised as a health rating. One and a half hours later, the authors presented participants with groups of six pictures on the screen and instructed them to select the familiar one as quickly as possible, using the keypad.
6. *Neurophysiological correlates of social stimuli.* Seven out of 19 studies collected a neurophysiological measure. Two out of six studies measured brain activity during the tasks discussed above. In particular, Gingnell et al. (2015), by means of fMRI, investigated the activation of amygdala, insula, anterior cingulate cortex (ACC), inferior frontal gyrus (IFG)

and medial frontal gyrus (MFG) in response to emotional faces as neural correlates of emotion recognition. Raz (2014) used an oddball task to study ERP in response to neutral/angry faces and shapes. Rutherford et al. (2016) in two different tasks monitored the P300 ERP component in response to the presentation of infant facial expressions (i.e., happy, distressed and neutral) for 500 ms and in response to the presentation of the sound of an infant crying for 2000 ms. Rutherford et al. (2017) observed the N170, P300 and the Late Positive Potential (LPP) ERP components during a task composed by 1 s trials in which distressed and neutral faces of both adults and infants, as well as houses, were presented. By means of the near-infrared spectroscopy (NIRS) technique, Roos et al. (2011) monitored brain activity of the prefrontal cortex (PFC) during an emotion recognition task involving the presentation of dynamic facial expressions of anger, disgust, fear and happiness. Each face was presented for approximately 2 s, and only PFC activation in response to fearful faces was extracted for further analyses. The only study that focused on an endocrine measure in response to social stimuli was that by Murphy et al. (2015). These authors collected saliva samples for cortisol analysis at five time points in response to a 6 min video clip depicting distressed young infants. The samples were collected in five different moments before and after the presentation of the video clip (30 min and just before the video clip, just after, 15 min and 30 min following the end of the video clip). Finally, one study focused on the autonomic response toward infant distress (Pearson et al., 2012a). After 8 min baseline recording, four of each of the audio and video stimuli were presented for 6 s with an interstimulus of 12-25 s. Two kinds of stimuli were presented, a crying audio clip played concurrently with the presentation of infant distressed facial expressions or a flashing computer screen during a white noise. Change in systolic blood pressure and change in pulse rate were recorded.

3.6.Endocrine measures

Four of 19 studies reported endocrine measurements. Roos et al. (2012, 2011) used blood and saliva samples to measure levels of cortisol, estrogen, progesterone and testosterone. Gingnell et al. (2015) measured progesterone and estradiol blood levels, and Murphy et al. (2015) obtained cortisol levels from saliva samples.

3.7. Depression and anxiety

Thirteen studies reported a measure of anxiety. In seven studies, authors used the State Trait Anxiety Inventory (STAI, Spielberger, 1985), a widely used self-report of anxiety symptoms, and in five studies, the revised Clinical Interview Schedule (CIS-R, Lewis et al., 1992), a fully structured diagnostic interview, was administered. Rutherford et al. (2017) required participants to complete the Beck Anxiety Inventory (BAI, Beck and Steer, 1990), a 21-question multiple-choice self-report inventory for measuring the severity of anxiety.

Twelve studies reported a measure of depression. Seven presented the results of the Edinburgh Postnatal Depression Scale (EPDS, Cox et al., 1987), a self-report measure of postpartum depression symptomatology that has also been largely used in samples of pregnant women (Murray and Cox, 1990). Five studies used the Clinical Interview Schedule-Revised (CIS-R; Lewis et al., 1992). Macrae et al. (2015) used the CIS-R to select a group of pregnant women with a proper ICD-10 (World Health Organization, 1992) diagnosis of depression, and the other studies included depressed women with at least one symptom of depression. Two studies used the Center for Epidemiological Studies Depression Scale (CES-D, Radloff, 1977), two studies administered the Beck Depression Inventory (BDI, Beck et al., 1961), and one study used the Montgomery Asberg Depression Rating Scale-Self report (MADRS-S Montgomery and Asberg, 1979). All these instruments are commonly used self-reports for depression symptomatology.

4. Discussion

The aim of this study was to systematically review the published literature regarding the effects of pregnancy on women's social cognition (cfr. Table A) and the effect of anxiety and depression (cfr. Table B). Nineteen studies were included, eight in Table A and 11 in Table B. On one hand, pregnancy was considered a period of great susceptibility as women prepare for motherhood. On the other hand, the studies differed in design, measures and results to an extent that made it impossible to reach definitive meta-analytic conclusions. However, similar results across multiple methodologies suggest that the effects are not task-dependent.

In the following paragraphs, we review findings regarding this review's two research questions. In addition, other critical issues are presented, and questions for future directions are addressed.

4.1. Does pregnancy affect face processing?

Despite the growing interest in pregnancy's role in modulating face processing, the study's methodologies were widely heterogeneous. However, as presented in Table A, the majority of studies reported a significant change in some aspects of face processing related to pregnancy. In particular, all but two of the pregnant-control women studies and the longitudinal studies showed a significant role of pregnancy in influencing the processing of human faces. Roos et al. (2011) and Cobey et al. (2015) reported no significant differences between pregnant women and controls. However, it should be noted that the first study involved a very small sample (nine controls vs. 10 to 12 pregnant women), which is inadequate to test the effects' sizes found in the other studies. In addition, this study showed results in the expected direction but only a trend for statistical significance. The second study tested a very specific dependent variable (i.e., preference for masculine or feminine faces) that is very different from that in the other studies that focused on emotional expressions or perception of health in human faces, so it is not inconsistent with the other findings, as it tests a different hypothesis.

Although it is limited, the remaining evidence seems to verify that pregnancy affects face processing. In particular, emotional faces appear to be perceived differently during pregnancy even though the studies do not agree on the specific emotions that elicit the different responses. Pearson et al. (2009) found that women in early pregnancy have an enhanced ability to encode negative but not positive emotions, compared to women in late pregnancy. Roos et al. (2012) showed an increase in selective attention to fearful faces but not happy or angry faces. At least partially in contrast, Raz (2014) noticed that the P300 ERP component elicited by emotional faces (i.e., angry faces) was lower among pregnant women than in the control group. Furthermore, this P300 modulation as a function of pregnancy was selectively observed for emotional faces but not for neutral facial expressions and shapes. Finally, Gingnell et al. (2015) found an amplified reactivity of the insula and the inferior frontal gyrus (IFG) in the early postpartum period in response to emotional faces. In sum, we can assert that these findings are suggestive of a modulation of emotional-face processing although the specific direction of this modulation is not presently clear. In this vein, we invite scholars to provide more research to determine whether the processing of emotional expressions benefits from the state of pregnancy. The proposed evolutionary hypothesis of an augmented attention toward emotional faces due to the higher vulnerability of pregnant women does not explain why the effect is inconsistent, especially for angry faces (e.g., Roos et al., 2012). However, we must note that all the studies used different methodologies and that no replication study has been published until now. Indeed, the very same evolutionary explanation is specifically consistent with the results of two other studies that reported that pregnant women were better at recognizing apparent health in faces (Jones et al., 2005) and in remembering adult faces, especially of males (Anderson and Rutherford, 2011). Both these abilities could be extremely useful to survive in a potentially dangerous social environment for pregnant women. The hypothesis of an improved memory for faces is particularly intriguing because the documented pregnant women's memory deficit could represent a trade-off due to an augmented allocation of resources to the social cognition domain (Anderson and Rutherford, 2012).

Finally, none of the studies clarified whether infant faces can be processed differently during pregnancy when compared to adult faces and a control group. In fact, infant faces are processed differently from adult faces (Proverbio et al., 2006; Riem et al., 2017b, 2017c), and that the responses to infant faces differ between nulliparous and parous women (Peltola et al., 2014; Proverbio et al., 2006; Thompson-Booth et al., 2014). Because pregnant women will be asked soon to interpret the new role of mother and engage in parenting behaviors, pregnancy could likely represent a transformation period that prepares women to process infant stimuli. Notably, processing infant faces is one of the basic caregiving abilities and helps determine maternal sensitivity (Leerkes et al., 2014). Future research should primarily focus on the hypothesis of pregnancy's role in shaping women's response to infant stimuli, considering the relevance of maternal behavior for children's development and the importance of designing early interventions for prevention (Bakermans-Kranenburg et al., 2003).

4.2. Are depression and anxiety associated with face processing during pregnancy?

Fifteen studies addressed the issue of the association between anxiety and depression during pregnancy and women's performance in various tasks involving face processing. In particular, eight studies reported findings on anxiety levels and 11 on depression.

4.2.1 Anxiety

One of the studies (Murphy et al., 2015) did not report results regarding the effect of anxiety even though participants were asked to report their levels. Of the seven remaining studies, five reported significant effects of anxiety, and two did not find significant associations with face perception. Results were mixed, especially regarding the encoding of specific adults' emotional expressions and the task involved. Overall, it seems that fearful faces are most often associated with anxiety levels. Fearful facial expressions are, indeed, better encoded (Pearson et al., 2009) and are linked to an increase in PFC activity during pregnancy (Roos et al., 2011) as well as an increase in IFG and insula activity during the early postpartum period (Gingnell et al., 2015). However, Roos et

al. (2012) found no association between selected attention to fearful faces and anxiety. Angry faces received slightly less attention but seem to be processed depending on anxiety at an explicit level (i.e., perceived as more disgusted, Gil et al., 2011) and at an implicit level (i.e., better encoding, Pearson, 2009). In the early postpartum period, IFG and insula activities have been found to be associated with angry faces, as well (Gingnell et al., 2015). Sad-adult-face processing (implicitly and explicitly) seems not to depend on anxiety levels during pregnancy (Gil et al., 2011; Pearson et al., 2009; Rutherford et al., 2017). Finally, no findings are reported for the association between implicit measures of happy expressions and anxiety, but no results are found when participants are explicitly asked to rate the pictures (Gil et al., 2011). Surprisingly, only two studies used infant faces as stimuli in addition to adult faces. The first one used explicit evaluations of various emotional expressions (Gil et al., 2011) and revealed that neutral faces were perceived as sadder and less neutral depending on participants' anxiety levels, and sad faces were rated as sadder. Notably, in this study, the association of anxiety with infant-face ratings was much clearer than with adult-face ones. Finally, Rutherford et al. (2017) found that the only ERP component associated with anxiety during pregnancy was the LPP in response to neutral infant faces but not to sad infant faces or neutral and sad adult faces. The authors interpreted this pattern of findings as a bias in anxious women toward perceiving ambiguous infant facial expressions as more negative, which is consistent with the evidence provided by Gil and colleagues' study. Notably, the same LPP effect was found during the postpartum period in another study (Malak et al., 2015).

In sum, it seems that during pregnancy, high levels of anxiety may be associated with more negative perceptions of negative emotional faces, similar to nonpregnant socially anxious individuals (Moser et al., 2008). Notably, no study focused on real clinical populations. On one hand, this absence could explain why not all the studies found clear-cut effects, but on the other hand, anxiety could play an adaptive role, at least at some point of the pregnancy. In fact, anxiety levels during pregnancy tend to rise (Ashley et al., 2016), and increased attention to negative adult and infant stimuli could have adaptive effects. Higher reactivity to negative adult faces could indeed

be protective of the fetus. Even more important, higher reactivity to infant faces could represent a mechanism of adaptation to the future role of mother and the importance of understanding children's needs.

As a caveat, a recent systematic review found that anxiety measurements during pregnancy should distinguish between anxiety related to the concerns of pregnancy and a more generalized anxiety (Brunton, Dryer, Saliba, & Kolhoff, 2015) because evidence shows that the former is more relevant to maternal processing and later child outcomes. Therefore, future studies should focus more on specific types of anxiety during pregnancy as well as the effect of anxiety in clinical populations. Finally, no study explored the association between anxiety-related face processing during pregnancy and actual postpartum parental behavior or later infant outcomes. Filling this gap could provide resourceful insights into the possible targets of interventions aimed at reducing the potentially negative but preventable effects of anxiety during pregnancy.

4.2.2. Depression

Regarding the depression effect, one of the 11 studies (Rutherford et al., 2017) reported significant associations between depression and the LPP and P300 ERP components, but the authors do not explain or interpret these effects. Of the remaining 10 studies, eight reported significant effects of depression during pregnancy on face processing, and two showed insignificant results.

Only three studies involved adult faces as stimuli. One found no association between neural responses to adult faces (i.e., activation of amygdala, insula, ACC, IFG and MFG) and depression in early the postpartum period (Gingnell et al., 2015) and did not involve infant stimuli. In contrast, Pearson et al. (Pearson et al., 2010) studied the attentional bias toward adult and infant faces and found no effect of depression on adult-face processing, but only nondepressed women showed a significant bias toward distressed infant faces. Finally, a third study focused on the explicit evaluations of adult and infant emotional faces and found no effect of depression on the perception

of adult faces (Gil et al., 2011). With this limited evidence, we could suggest that depression during pregnancy is not involved in the processing of adult faces, even if more research is needed. In particular, no study implied clinical populations, but the possibility that more severe symptoms could have an effect anyway was not excluded.

Regarding the attentional bias towards infant distress, two studies reported findings, using the same paradigm. Pearson et al. (2011), in a subsample of the previous study (Pearson et al., 2010), did not replicate the association between depression scores and the attentional bias, but the authors argued that the study's power was insufficient to detect an effect. Interestingly, they found a negative association between the attentional bias during pregnancy and the self-reported quality of mother-child bonding in the postpartum period. The effect of depression on the attentional bias was then confirmed in a following study (Pearson et al., 2013b) in a different group of clinically depressed pregnant women. The study was a randomized clinical trial where CBT was administered to half of the depressed group of women and led to the normalization of disrupted attentional processing of infant distress. In two further studies, the authors investigated the possible mechanisms of the association between depression and the decreased attentional bias during pregnancy. They found that depressed participants showed greater systolic blood pressure (Pearson et al., 2012a) and more cortisol reactivity (Murphy et al., 2015) when exposed to infant distress.

Four studies presented findings on explicit evaluations of infant emotional expressions. Gil et al. (2011) showed that depression was associated with evaluations of neutral infant faces as less neutral and sadder. In clinically depressed pregnant women, Macrae and colleagues (2015) found that depressed women were less willing to comfort distressed infants and more willing to turn away from them than nondepressed women during pregnancy. Bernstein et al. (2014) studied the effect of traumatic symptoms (depressive symptoms are a subgroup of these) on predicting pregnant women's tendency to classify emotional infant faces and children's subsequent attachment one year after birth. They found that traumatic symptoms were associated with a greater number of emotions identified as sadness. In addition, the number of emotions classified as angry and sad significantly

predicted the probability of the development of the child's disorganized attachment. Surprisingly, one study found no association between depressive symptomatology and pregnant women's ability to correctly evaluate negative emotions in audio-video clips of distressed infants (Leerkes, 2010). It has to be noted, however, that the measure of "failure to detect negative emotions" was operationalized as the number of times the participant "minimized" (i.e., rated the facial expression lower than the rating provided by reliable trained raters) and the number of times she used a nonemotional or positive word to describe infant distress. It is possible that this kind of score underestimates depressed participants' tendency to consider infants sadder while representing a quite accurate measure of maternal emotion dysregulation in infant care. The measure's relevance is confirmed by this score's ability to predict the actual maternal sensitivity assessed 6 months after birth.

Only one study (Rutherford et al., 2016) focused on the brain correlates of infant-face processing during pregnancy and the effect of depressive symptomatology. The authors found that depression scores during pregnancy are associated with decreased P300 amplitude in response to distressed infant faces. P300 has been linked to an increase in the allocation of attentional resources in response to infant stimuli in mothers (Bick et al., 2013; Grasso et al., 2009; Proverbio et al., 2006).

In sum, depression is likely to be associated with the processing of infant faces during pregnancy even if not all the studies provide evidence consistent with this conclusion. More specifically, it is possible that depressed pregnant women perceive distressed and neutral infants as sadder. In addition, behavioral and neural evidence suggests that the salience of distressed infants is dependent on antenatal depression. Furthermore, it seems that the effects of depression are confirmed in clinical and nonclinical populations although further studies investigating this issue are needed. Besides the studies' low homogeneity, another of their limitations is the difficulty (due to the low number of studies) in interpreting the results regarding the kind of depression measure used. For instance, it is possible that measures of depression developed specifically for pregnancy

or the postpartum period (e.g., EPDS) could be more sensitive to changes in the performance to tasks that involve infant stimuli.

4.2.3. Can we determine the specific contribution of depression and anxiety?

Because depression and anxiety show high levels of comorbidity (Lee et al., 2007; Pollack, 2005), an important issue is whether we can distinguish between the unique and specific contributions of each kind of symptomatology to face processing. In fact, disentangling the effects of anxiety and depression would inform clinical practices of the most rewarding targets for interventions. In addition, comorbidity between anxiety and depression during pregnancy may constitute a specific risk factor for face processing (LeMoult and Joormann, 2012) because its effect on predicting children's outcomes has already been shown (Field et al., 2010). Unfortunately, although 10 studies collected anxiety and depression measures, only two of them (Gil et al., 2011; Rutherford et al., 2017) tested the concurrent effects of depression and anxiety symptomatology on the face-processing measure. Therefore, no conclusive evidence can be drawn. Specifically, Rutherford and colleagues explored the effect of anxiety measured with the Beck Anxiety Inventory, controlling for depression measured with the Beck Depression Inventory. Results show that depression has a main effect on P300 amplitude, even if anxiety has no significant association with this component. More important, anxiety's effect on the LPP remained significant after researchers controlled for the significant effect of depression. However, even if the anxiety effect is unique and specific, the depression one is not in the aims of the study and is not investigated in interaction with facial expressions or age of the stimuli (adult vs infant faces). The analytical approach used by Gil et al. based on stepwise linear regression, in contrast, enables researchers to determine which clinical score was a better predictor of the evaluation of the neutral baby faces when both were significantly associated with the emotional judgment. Results show that depressive symptomatology was the only predictor of neutral evaluation of a neutral baby face. In contrast, state anxiety was the only predictor of how sad a neutral baby face was perceived. From these

scarce results, no pattern of the specific contribution of depression or anxiety to face processing during pregnancy can be identified. Even more problematic, on this point, no hypotheses have been proposed to disentangle anxiety and depression effects that can be empirically tested. Relying on studies with nonpregnant nonparent subjects, it seems that depressed patients require greater intensity of emotion to identify happy expressions and less intensity to identify sad than angry expressions, compared with anxious patients or controls. Anxious participants were better at identifying the angry than the sad expressions (Joormann and Gotlib, 2006). We could suggest a similar effect during pregnancy even though we do not have evidence to support this claim at all. Future studies should be designed to fill this gap and build interventions to target specific symptomatology based on the desired outcome.

Regarding comorbidity, no study focused on this topic in pregnancy even though several of the reviewed studies could potentially address this issue. Notably, the studies that used the CIS-R to screen for depressive symptomatology did not differentiate the overlaps between depressive and anxiety symptomatology. For instance, Pearson et al. (2012a) reported that in the depression group (N = 38), 24 women were also experiencing one or more symptoms of anxiety, but the small sample size did not allow them to consider specific effects of anxiety and depression.

In conclusion, anxiety and depression likely affect face processing during pregnancy, and the effect of depression is potentially more selectively involved in infant-face processing. This finding could occur due to a disruption of the functionality of the brain reward system, which is more involved in the perception of infant faces than of adult ones (Kringelbach et al., 2016). Also, regarding the effects of depression and anxiety in pregnancy on face processing, further studies seem necessary to clarify their effect with greater precision. However, we can suggest that pregnancy is a relevant event in a woman's life for studying individual differences in face processing. Moreover, although only three studies (Bernstein et al., 2014; Leerkes, 2010; Pearson et al., 2011) addressed the issue of the relevance of face processing during pregnancy for the future

mother-child relationship or infant development, it is notable that they have reported significant effects.

In the following paragraphs, we try to briefly provide answers to some additional questions related to changes in social cognition abilities during pregnancy, the potential impact of these changes on infants' development and whether and how it could be possible to use paradigms of face processing to tune psychological intervention aimed at preventing depression and anxiety during pregnancy and the postpartum periods.

4.3. Do hormonal changes play a role in social cognition during pregnancy?

Only three studies provided direct hormonal measures, and they evaluated different hormones. In addition, all the studies included small sample sizes, used different paradigms to measure adult-face processing and collected hormone samples at different times in pregnancy or the early postpartum period. Gingnell and colleagues (2015) found no association between progesterone/estradiol and brain activation in response to fearful or angry faces during the early or late postpartum period. In pregnancy, cortisol and testosterone (but not progesterone and estrogen) are associated with prefrontal cortex activation in response to fearful faces (Roos et al., 2011). Roos et al. (2012) found different results for the second and the third trimesters of pregnancy: estrogen and progesterone were associated with an increase in selective attention to fearful faces during the second trimester, but cortisol showed a negative correlation during the third trimester.

In sum, the scarcity of evidence, the small sample sizes and the inconsistent results do not allow for conclusive remarks. Despite these limitations due to the insufficient number of studies on this topic, the endocrine system is a likely candidate for the mechanisms of the above mentioned changes in face processing. More extensive research is needed also to determine whether the association between the endocrine system and behavioral responses is specific to pregnancy.

4.4. What are the neural correlates of social cognition changes during pregnancy?

Identifying patterns of the neural correlates in pregnant women is difficult in light of the small number of studies available. In fact, whether numerous studies investigated brain activity in mothers, compared to nonmothers, little has been done to explore pregnancy's effects on neural activity. However, some considerations can be provided.

Because women go through drastic physical and psychological modifications that expose them and their fetuses to several risks, it appears logical and evolutionarily adaptive to develop multiple (and more reactive) neural responses toward (some) social stimuli, in particular facial expressions of threat.

Three studies (Gingnell et al., 2015; Raz, 2014; Roos et al., 2011) investigated whether pregnant women's neural activity differs from that of nonpregnant women in response to social stimuli. Only adult faces have been used as stimuli across these studies. Each study used different neuroimaging methodologies (i.e., fMRI (Gingnell et al., 2015), NIRS (Roos et al., 2011), ERP (Raz, 2014)) and different tasks. Therefore, it is difficult to compare the results. However, it seems that prefrontal cortex activation in response to fear-relevant stimuli changes in various stages of pregnancy in the same subjects, even if it they do not differ from the controls (Roos et al., 2011). Clearly, the within-subject effect is more powerful than the between-subjects one. Raz (2014) found that the P300 amplitude in response to angry faces was lower in pregnant women than in the controls. Notably, among pregnant women, P3 amplitude was greater for shapes than for faces, but the opposite pattern of findings was reported for the control group. Finally, brain activation due to emotional faces − in areas implicated in social cognition, e.g., inferior frontal gyrus and insula − was lower in the early postpartum period than in the late postpartum period. This finding could suggest a primary role of experience in shaping brain adaptation to caregiving tasks or at least that pregnancy starts a process of change that continues after birth (Parsons et al., 2017).

Two studies focused on the effect of depression and anxiety on the ERP response to infant faces. In particular, Rutherford et al. (2016) found decreased P300 activity in depressed women in

response to distressed infant faces. This finding, together with the behavioral evidence, may underline an avoidant style of attentional processing in pregnant women displaying depressive symptomatology. On the contrary, anxiety levels did not predict P300 amplitude in pregnant women (Rutherford et al., 2017). However, LPP activity in response to neutral infant faces seems to depend on anxiety. This last result could be interpreted as prolonged attention to ambiguous stimuli.

To summarize, all the studies that involved brain-imaging techniques to study social cognition in pregnancy have found some kind of significant results, which suggests that the striking results found by Hoekzema and colleagues (2016) on the morphological brain modifications due to pregnancy could have a functional counterpart. Future studies should consider the opportunity to use longitudinal designs able explore when during pregnancy the brain is most sensitive to social stimuli and how this sensitivity impacts the subsequent parental role and infant development.

4.5. Pregnancy and Motherhood: specific or cumulative effects?

Mothers' reactions to infant stimuli is different from nulliparous women's reactions to these same stimuli (Oliveira et al., 2017; Peltola et al., 2014; Proverbio et al., 2006; Thompson-Booth et al., 2014). Moreover, evidence proves a long-term effect of pregnancy in shaping brain structure (Hoekzema et al., 2016), and these modifications endured for at least two years after birth. It is unclear whether this effect is due to the alterations (mainly hormone-based) of pregnancy or the experience with the child. However, a recent study showed that the duration of motherhood has incremental effects on the perception of infant vocal cues (Parsons et al., 2017). This finding could suggest that both mechanisms (i.e., pregnancy and the interaction with the child) are probably involved in this process, starting and maintaining maternal specificity in processing infant cues. Unfortunately, none of the studies included in the present review may help disentangle these effects. In fact, most of the studies did not include only primiparous women, and only a few controlled for a parity effect in the analyses. Notably, no study tested pregnant primiparous women versus controls and postpartum mothers. This is one of the main limitations of the present review that, however,

depends on the scarcity of the evidence currently available. Not only is more research needed to clarify changes in social cognition in primiparous pregnant women and in pregnant women who are already mothers; it should also be noted that when social cognition abilities of pregnant women are confronted with those of controls, some studies might have failed to detect any effects because some participants in the control group were mothers.

4.6. Does social cognition during pregnancy affect postnatal infant development?

Only one study presented results regarding the association between maternal face processing during pregnancy and later infant development. Specifically, Bernstein and colleagues (2014) found that the prenatal maternal ability to correctly classify infants' emotions predicted infants' attachment security vs. disorganization at 18 months whereas high betrayal traumatization during childhood and maternal sensitivity did not. On one hand, this finding confirms the relevance of correctly perceiving emotions during pregnancy for infant development. On the other hand, no association between face processing and actual parenting behavior (i.e. maternal sensitivity) was found.

Two other studies described results that are associated with postpartum measures related to the infant-mother relationship. Pearson et al. (2011) found that a greater attentional bias during pregnancy predicted a better mother-child relationship 3-6 months postpartum (based on maternal self-report). Leerkes et al. (2010) found that the ability to detect infant distress during pregnancy predicted the quality of maternal sensitivity 6 months postpartum.

In sum, evidence (limited so far) shows that face processing during pregnancy may be a predictor of real mother-child interactions and infant development. A crucial but still unclear issue is the association between the ability to identify children's emotions during pregnancy and later maternal sensitivity. In fact, not only is maternal sensitivity considered one of the main predictors of infant development (Berry et al., 2017), but its precursors during pregnancy are highly relevant

(Leerkes et al., 2014) because they represent possible targets of early prevention programs (Evans et al., 2017; Letourneau et al., 2017a; Pearson et al., 2013b).

4.7. Is face processing during pregnancy a target for possible programs aimed at preventing depression or anxiety?

Recent reviews (Evans et al., 2017; Letourneau et al., 2017b) showed limited evidence of the efficacy of prenatal interventions in the reduction of anxious and depressive symptomatology during pregnancy. In particular, Evans and colleagues (Evans et al., 2017) found no beneficial effect in the reduction of anxiety, but Letourneau et al. (2017b) reported more optimistic results on antenatal depression. In particular, two interventions reported that improvement in antenatal depressive symptoms had beneficial effects for infant development (Netsi et al., 2015), even if only in one case the target treatment was superior to the standard treatment (Milgrom et al., 2015).

One study of our review shows that a psychological intervention during pregnancy may positively affect attentive processes affecting maternal sensitivity in depressed pregnant women (Pearson et al., 2013b). The authors conducted CBT to normalize the disrupted attentional bias of depressed pregnant women toward distressed infant faces. The findings strongly suggest that the CBT restored the adaptive bias in the previously depressed women. It is unclear whether this was a specific change in the processing of infant faces or a general effect of rewarding stimuli. We could speculate that face processing is a promising mechanism of change during pregnancy. In fact, more research is needed to determine whether the face-processing plasticity of pregnancy can result in a cascade effect with consequences for maternal behaviors and potentially infant development. For instance, the maternal ability of mirroring infant facial expressions at 2 months predicts the quality of infants' gestures in producing the same expressions observed at 9 months (Rayson et al., 2017). It is still unknown whether face processing during pregnancy could be considered a precursor of similar postpartum processes, but this seems a promising area for future research.

4.8. Limitations

The main limitation of the present systematic review is the difficulty in identifying studies that could be considered homogeneous enough to test the effect of pregnancy with a meta-analytical approach. Methodologies and measures were very different across studies to justify the use of a composite test.

To take into account most of the literature, our selection criteria were very broad. In addition, our operationalization of the concept of "face processing" was quite inclusive, to the extent that we considered every task that included any kind of response to adult or infant faces. On one hand, this inclusion enabled us to present a detailed picture of the state of the art; on the other hand, it contributed to the difficulty in drawing final conclusions for each question.

Many studies lack the power (e.g., Roos, 2011) to detect smaller effects, which would still be meaningful. Only a few replication studies have been conducted (and some failed to replicate the results), suggesting that all the effects presented and discussed in this review require replication. Moreover, some of the studies presented findings of only a subset of the collected data without specifying theoretical or methodological reasons to exclude some of the results. In conclusion, publication bias may be driving some of the results. However, we claim that a comprehensive review of the literature published so far can help highlight limitations to specify new ways to address them. Future directions of research have been presented, so we can concentrate our efforts on improving our knowledge of pregnancy's effects on face processing.

5. Conclusion

The present systematic review points out the relevance of pregnancy as a possible plasticity window for face processing and probably social cognition *tout court*. Far from being conclusive, research is only at the beginning in this field, but this review represents a first attempt toward unifying and systematizing various kinds of evidence. In particular, the field would largely benefit from three lines of research: (1) replication studies with adequate and preregistered sample sizes,

(2) a focus on differences between infant and adult faces and (3) studies on the differences between nulliparous, pregnant and parous women.

Finally, anxiety and depression seem to be associated with face processing during pregnancy. We could hypothesize that face processing helps cause the detrimental effects of antenatal maternal depression on future parental abilities and infant development, but so far, we have very limited evidence. In addition, other variables could moderate the association between anxiety or depression and parenting precursors, such as attachment (De Carli et al., 2016), childhood maltreatment (Riem et al., 2017a) or psychopathology (Sacchi et al., 2018).

Appendix A

Table A. Studies that address the issue whether pregnancy alters social cognition.

Article citation	*N*	*Design*	*Post partum*	*Parity*	*Depression Anxiety*	*Task*	*Social Stimuli*	*Outcome Measure*	*Hormonal measures*	*Results*
Jones 2005 (Study 4)	115 pregnant women 857 controls	Pregnant (across all trimesters)/non pregnant women	-	Not specified	-	Preference for faces with health appearance manipulated.	Neutral adult male faces manipulated for apparent health	Self-reported preference for one of each couple of faces presented.	-	Pregnant women expressed greater attraction to apparent health than women with natural cycles.
Pearson[a], 2009	101 women at early pregnancy: 76 again in late pregnancy.	Longitudinal study. Early (7-14 W) and late pregnancy (33-39 W).	-	PP and MP, parity controlled in the analyses.	Anx: CIS-R	A facial expression recognition task took from SASI[b].	Adult faces showing happiness, sadness, fear, anger, disgust and surprise.	Accuracy in encoding facial expressions of emotions.		Women in late pregnancy were better in decoding negative emotional expressions (fearful, angry, disgusted, sad faces). Happy and surprise faces were identified too often therefore excluded from analyses. Symptoms of anxiety were associated with greater ability to encode fearful and angry faces But not sad and disgusted.
Anderson, 2010	20 pregnant vs 20 non pregnant (male condition); 19 vs 19 (female condition)	Pregnant (across all trimesters)/control	-	Pregnant: PP, MP Non pregnant: NP, PP, MP	-	Recognition accuracy task	Adult neutral faces.	Accuracy at recognizing faces.	None	Pregnant women were better at recognizing faces, particularly for own-race male faces
Roos, 2011	Pregnant women assessed during: trimester 1 =10, trimester 2= 12, trimester 3= 10. non pregnant controls=9	Longitudinal study. Pregnant/non pregnant women, pregnant women assessed at trimester 1 (13-14 W), 2 (22-23 W) and 3 (32-33 W).	-	Not specified	Anx: STAI Distress: K-10	Facial Stroop task (masked and unmasked); Emotion Recognition Task during NIRS assessment.	Emotion Recognition Task: disgusted, fearful and happy adult faces. Facial Stroop Task: fearful and neutral adult faces.	Activation of prefrontal cortex (PFC) in response to fearful faces. RT for the masked and unmasked Stroop Task	Cortisol, estrogen, progesterone testosterone.	PFC activation in response to fearful faces compared to rest. No difference in PCF activation between pregnant women and controls, but within pregnancy higher activation in trimester 1 compared to 3 (but not 2). No association between PFC activation and stress/anxiety or selective attention in full sample. In pregnant sample: increased PFC activation associated with stress and state and trait anxiety; decreased PFC activation associated with selective attention to masked (but not unmasked) fearful faces. In pregnant women association between PFC activation and cortisol and testosterone, but not estrogen and progesterone.

Roos, 2012	44 pregnant women; 25 non pregnant controls	Longitudinal study. Pregnant /non pregnant women. Pregnant women assessed at trimester 2 (22-23 W) and 3 (32-33 W)	-	Not specified	Anx: STAI Distress: K-10	Emotional Stroop task	Fearful, angry, happy and neutral adult faces	Selective attention to emotional faces	Cortisol, estrogen, progesterone testosterone.	No difference in selective attention between trimester 2 and 3. Augmented selective attention to fearful (but not angry or happy) faces in pregnant women compared to controls. Distressed pregnant women had increased selective attention to fearful faces compared to distressed controls. Selective attention to fearful faces was positively correlated with estrogen and progesterone at trimester 2 and negatively with cortisol at trimester 3.
Raz, 2014	pregnant=17; non-pregnant=19	Pregnant (26-36 W)/non pregnant women	-	Pregnant: PP, MP Non pregnant: NP, PP, MP Groups matched for number of children.	Anx: STAI-Y2	Online Continuous Performance Test[c]; Visual emotional oddball task with neutral or angry faces and shapes during EEG/ERP recording	Adult male faces with neutral or angry facial expressions.	OCPT: Error rate, RT and RT consistencies OddBall task: amplitude and latency of P3 and N170, errors rate and RT.	None	Sustained attention was worse in pregnant women only for response consistencies (but not error rates and RT). Response inhibition was worse in pregnant women for each index. In the oddball task: no difference in omission errors; higher rates of commission errors for faces but not shapes in pregnant women; lower RT and higher RT consistency in pregnant women. Pregnant women show lower P3[d] amplitude and longer latency in response to angry faces compared to controls (but not neutral faces or shapes). N170[e] amplitude was higher in pregnant women for faces but not for shapes. No effects for N170 latency.
Cobey, 2015	28 pregnant women; 75 controls (42 use HC and 33 RC).	Longitudinal study (pregnant women at 13-31 W and in postpartum). Pregnant/non pregnant women.	12 W after delivery	Pregnant: PP, MP Non pregnant: NP	-	Face pair rating task	20 pairs of faces (a masculine and feminine version) with neutral expressions.	Subjective preference for masculine or feminine male faces	None	No difference in preference for masculine or feminine male faces between control groups and pregnant group. Postpartum women show less preference for masculine male faces than pregnant and control women under hormonal contraception (but not those regularly cycling). No effect for female faces.
Gingnell, 2015	13 healthy postpartum women, 15 naturally cycling controls	Longitudinal study during postpartum. Postpartum/controls. Controls assessed in the late luteal phase and in the mid-follicular phase.	48 h and 4-6 W after delivery	Not specified. Control subjects were or >1year post partum or NP.	Dep: MADRS-S; EPDS. Anx: STAI-S	Emotional face matching task[f] during fMRI session.	Angry and fearful adult faces	Amygdala, insula, ACC, IFG and MFG activation in response to emotional faces.	progesterone and estradiol.	Insula, IFG and lMFG activations were lower in the early vs late postpartum. At early postpartum insula and IFG correlate positively with STAI-S. At late postpartum MADRS-S correlates positively with IFG and insula. No effects for EPDS. No correlations between brain and estradiol or progesterone. IFG and insula reactivity higher in postpartum vs controls.

[a]Pearson (2009, 2010, 2012) used the same sample for all these studies. [b]SASI : Schedules for the Assessment of Social Intelligence= standardized set of measures of social-cognitive competence (Skuse, 2005); [c]OCPT: Online Continuous Performance Test: a non emotional test of sustained attention and response inhibition (Raz, 2014); [d]P3 = (a positive peak at around 300 ms) measured by Event-Related Potentials, is sensitive to familiarity and *novelty;* [e]N170= (a negative peak at 170 ms) early ERP's associated with

structural encoding and perception of faces; [f]Emotional face matching task: subjects are asked to match one of two simultaneously presented images with an identical target image Hariri et al., 2002; W:weeks; Anx: Anxiety; Dep: Depression; RT: Reaction times; MP: multiparous; NP: nulliparous; PP: primiparous; HC: Hormonal contraception; RC: Regularly cycling; *Clinical measures: CIS-R* = Clinical Interview Schedule–Revised (Lewis et al., 1992); EPDS: Edinburgh Postnatal Depression Scale (Cox et al., 1987); K-10: Screening Tool to Assess Distress (Kessler et al., 2003); MADRS-S: self-rated version of the Montgomery-Åsberg Depressive Rating Scale (Montgomery and Asberg, 1979); SASI : Schedules for the Assessment of Social Intelligence (Skuse, 2005); STAI: Spielberg State-Trait Anxiety Inventory (Spielberger, 1985); *WAIS*: Wechsler Adult Intelligence Scale (Wechsler, 1997);

Neuropsychological measures: EEG: Electroencephalography; ERP: Event-Related Potentials; (f)NIRS: Functional Near-Infrared Spectroscopy (2007); fMRI: functional magnetic resonance imaging.

Brain areas: ACC: anterior cingulate cortex; IFG: inferior frontal gyrus; MFG: middle frontal gyrus; lMFG: left middle frontal gyrus; PFC: prefrontal cortex;

Appendix B

Table B. Studies that describe the effect of anxiety and depression in social cognition during pregnancy.

Article citation	*n*	*Desig*	*Post partum*	*Parity*	*Depression Anxiety*	*Task*	*Social Stimuli*	*Outcome Measure*	*Results*
Leerkes, (2010)	101	Longitudinal study, women were assessed during pregnancy (4 to 6 W before their due dates)	6 months	PP	Dep: CES-D[q]	Distress detection in infants faces during video clips. Assessment of mothers' goals in relation to infant distress.	10-s video-clips of infants displaying low-level and intense fear/anger	Emotion recognition and maternal sensitivity at 6 months.	Antenatal depressive symptomatology was not associated with emotion recognition, maternal goals and maternal sensitivity. Distress recognition and maternal goals during pregnancy predicted maternal sensitivity at 6 months. Postnatal depression symptomatology was associated with infant oriented goals and maternal sensitivity.
Pearson[bc], 2010	101	Women tested on an average gestation of 11 weeks (SD = 13 days)	-	PP and MP. Controlled in the analyses.	Anx: Cis-R Dep: CIS-R, EPDS	Attentional bias (go/ no-go trials) towards infant/adult emotional faces	Fearful, neutral and happy adult faces. Happy, distressed and neutral infant faces	RT in disengaging attention from infant/adult emotional faces	Slower disengagement from distressed infant faces (compared to neutral and happy) in non-depressed (but not in depressed) women. No difference between happy and neutral. No effects for adult faces.
Gil[d], 2011	79	Only postpartum measures.	3 days after birth	Not specified	Dep: EPDS; Anx: STAI	Emotional facial expression task	Adults and infant faces Angry, happy, sad and neutral faces of adults and infants. Angry and sad infant faces were combined.	Evaluation of emotional facial expressions on a 7 points scale on the intensity of 5 emotions: anger, happiness, sadness, neutrality and disgust.	Depression and state anxiety correlate with less neutral and more sad evaluation of neutral infant faces. State anxiety correlates with more disgusted evaluation of neutral and angry adults. Trait anxiety correlates with more sad evaluation of sad infants. Postpartum depression was the only predictor of the neutral evaluation of neutral infants, while state anxiety was the only predictor of sad evaluation of sad infants. No effects of external variables.
Pearson[b,c], 2011	75 in late pregnancy; 49 also during postpartum.	Longitudinal study: women assessed in pregnancy (34-39 W) and postpartum.	3-6 months postpartum	PM and MP	Dep: EPDS	Attentional bias towards distressed infant faces	Distressed or non-distressed infant faces.	PBQ	Attentional bias toward distressed infants during late pregnancy predicts maternal perception of mother child relationship after birth, after controlling for depression.
Pearson[b], 2012	72 women in early pregnancy; 51 also in late pregnancy	Longitudinal study: early pregnancy (7 - 14 W), late pregnancy (33-39 W)	-	PP and MP. Controlled in the analyses.	Anx: CIS-R Dep: CIS-R	Autonomic response task towards infant distress	Distressed infant audio clip and pictures of infant faces	Change in systolic blood pressure. Change in pulse rate towards infant distress.	Women with anhedonic symptoms of depression had larger systolic BP but not pulse rate in response to infant distress. No effect for control sound.

Pearson[c], 2013 [n]	75 women in early pregnancy pre intervention: CBT (n=12), usual care (n=12), non depressed women (n=51).	Longitudinal study. Pre-intervention session during early pregnancy (8 – 18 W) and then during late pregnancy (M = 32)	-	PP and MP	Anx: CIS-R Dep: CIS-R, EPDS	Attentional bias towards distressed infant faces	Distressed and non distressed infant faces	Reaction Times in disengaging from distressed infant faces	Depressed women have lower attentional bias for infant distress at baseline. Following intervention attentional biases become comparable to non-depressed women only in CBT group.
Bernstein, 2014	70 mother child dyads	Longitudinal study in high risk sample[e]: late pregnancy (third trimester) and postpartum	5 and 18 months postpartum	PM	Dep: CES-D[f]	IFEEL Picture System: participants rate infant faces on several emotions.	Positive, negative and ambiguous infant faces	Infants' secure vs disorganized attachment at 18 months	The ability to label infant emotions, the number of emotions classified as "sad" and "angry", adult history of traumatization and income, predicted attachment security versus disorganization. Only the number of emotions classified as sad correlates with adult trauma and traumatic symptomatology.
Murphy, 2015	53	11 - 18 W	-	PM	Dep: EPDS; Anx: STAI[g]	Cortisol reactivity was measure after a video of a distressed infant	6 min film depicting distressed young infants	Cortisol reactivity to infant distress	Main effect of depression and time in the change from baseline in salivary cortisol. No interaction but no group difference at baseline, while significant post stressor. Higher state anxiety in depressed group but levels rise in both group after the stressor. No effect of stress on PANAS but more negative scores in the depressed group.
Macrae, 2015[n]	105	Range 9 – 19 W	-	PM, MP. Parity controlled in the analyses	Dep: CIS-R, EPDS Anx: CIS-R Depression diagnosis based on ICD-10	Maternal Response Scales: presentation of emotional infant faces	Distressed, neutral and happy infant faces	Self reported ratings of children faces on three dimensions: "I want to comfort", "I want to turn away", "I feel anxious".	Depressed women were less likely to be in the highest vs lowest category for wanting to comfort distressed infants. They were more likely to be in the highest vs lowest category for turning away from neutral and happy faces. The effect on distressed infants remains after controlling for responses to neutral and happy infants.

Rutherford, 2016	36	34 and 38 W	-	Not specified	Dep: EPDS, BDI-II	Infant emotional faces and low/high distressed infant cry and a neutral tone during EEG recording.	Happy, distressed, and neutral infant faces, high/low-distress infant cry	P300[i] in response to emotional infant faces and infant cry	Depression symptoms are associated with attenuated P300 to distressed infant faces. No effect for happy/neutral faces and infant cry.
Rutherford, 2017	43	43 pregnant women during their third trimester (M = 34 W).	-	PP, MP	Anx: BAI, Dep: BDI	Perception of faces and houses during EEG recording	Neutral and distressed infant and adult faces	N170[l], P300, LPP[m] in response to infant and adult faces and houses	No effect of adult/infant face, anxiety and emotional expression on the N170. Significant 3-way interaction for the P300 but not significant correlation between anxiety and P300. Significant 3-way interaction for the LPP: association between anxiety and LPP, in particular in response to infant neutral faces. Significant results remained after controlling for depression.

No endocrine measure column was reported since no study implied any hormonal measure; [a]Chimeric-Face Task= the task consists of the presentation of faces composed of two hemifaces with two different expressions (smiling and neutral). The purpose of this task is to detect the participant's dominant visual field in the recognition of facial emotions (Bourne and Todd, 2004); [b]Pearson (2009, 2010, 2011, 2012) used the same sample for all these studies; [c]Pearson (2010, 2011, 2013) used the same attentional task, the only difference is that the first one (Pearson, 2010) used also adult faces and not only infant faces; [d]Gil (2001) assessed the sample also with TAS-20: The Toronto Alexithymia Scale (Bagby et al., 1994); [e]Bernstein (2014) used an high risk population sample with elevated depressive symptoms: cut-off CES-D ≥ 12 or risk problematic parenting: cut-off SSPP ≥11; [f]Bernstein (2014) study: to assess trauma symptoms and experiences : BBTS: Brief Betrayal Trauma Survey, TSC: Trauma Symptom Check-list, CHBT: Childhood High Betrayal Traumatization, AHBT: Adulthood High Betrayal Traumatization; [g]Murphy (2015) used PANAS: Positive and Negative Affect Scale(Watson et al., 1988) for the evaluation of the sample; [h]Murphy (2015) collected, in five time points, saliva's samples collection: 2 samples before the film, 1 immediately following the end of the film, 2 samples were collected 15 and 30 min following the end of the film respectively; [i]P300 = (a positive peak at around 300 ms) measured by Event-Related Potentials, is sensitive to familiarity and *novelty;* [l]N170= (a negative peak at 170 ms) early ERP's associated with structural encoding and perception of faces; [m]LPP (late positive potential) event-related potentials= sustained processing of salient visual information; [n]Pearsn 2013 e Macrae 2015 obtain data from the same broader sample; W:weeks; Anx: Anxiety; Dep: Depression; RT: Reaction times; MP: multiparous; NP: nulliparous; PP: primiparous; *Clinical measures:* AHBT: Adulthood High Betrayal Traumatization (Goldberg and Freyd, 2006); BAI: Beck Anxiety Inventory (Beck and Steer, 1990); BBTS: Brief Betrayal TraumaSurvey (Goldberg and Freyd, 2006); BDI-II: Beck Depression Inventory-II (Beck et al., 1996); CES-D: Center for Epidemiological Studies-Depression (Deoliveira et al., 2005)(Radloff, 1977); CHBT: Childhood High Betrayal Traumatization (Goldberg and Freyd, 2006); CIS: Clinical Interview Schedule-Revised (Lewis et al., 1992); EPDS: Edingburgh Postnatal Depression Scale (Cox et al., 1987); Handedness Questionnaire, from the Edinburgh Handedness Inventory (Oldfield, 1971); IFEEL: IFEEL Picture System (Emde et al., 1987); MRS: Maternal Response Scale (Macrae et al., 2015); PANAS: Positive and Negative Affect Scale (Watson et al., 1988); PBQ: Postpartum Bonding Questionnaire (Brockington et al., 2006); STAI: State Trait Anxiety Inventory (Spielberger, 1985); TAS-20: The Toronto Alexithymia Scale (Bagby et al., 1994); TSC: Trauma Symptom Checklist-40 (Briere and Runtz, 1989). *Neuropsychological measures:* EEG: Electroencephalography; ERP: Event-Related Potentials; (f)NIRS: Functional Near-Infrared Spectroscopy (2007); fMRI: functional magnetic resonance imaging. *Brain areas*: ACC: anterior cingulate cortex; IFG: inferior frontal gyrus; MFG: middle frontal gyrus; lMFG: left middle frontal gyrus; PFC: prefrontal cortex;

Bibliography

Ainsworth, M.D.S., Bell, S.M., Stayton, D., 1974. Infant-mother attachment and social development, in: Richards, M.P. (Ed.), The Introduction of the Child into a Social World. Cambridge University Press, London, pp. 99–135.

Anderson, M. V., Rutherford, M.D., 2012. Cognitive Reorganization during Pregnancy and the Postpartum Period: An Evolutionary Perspective. Evol. Psychol. 10, 147470491201000. https://doi.org/10.1177/147470491201000402

Anderson, M. V., Rutherford, M.D., 2011. Recognition of Novel Faces after Single Exposure is Enhanced during Pregnancy. Evol. Psychol. 9, 147470491100900. https://doi.org/10.1177/147470491100900107

Andersson, L., Sundström-Poromaa, I., Bixo, M., Wulff, M., Bondestam, K., ÅStröm, M., 2003. Point prevalence of psychiatric disorders during the second trimester of pregnancy: a population-based study. Am. J. Obstet. Gynecol. 189, 148–54.

Ashley, J.M., Harper, B.D., Arms-Chavez, C.J., LoBello, S.G., 2016. Estimated prevalence of antenatal depression in the US population. Arch. Womens. Ment. Health 19, 395–400. https://doi.org/10.1007/s00737-015-0593-1

Bagby, R.M., Parker, J.D.A., Taylor, G.J., 1994. The twenty-item Toronto Alexithymia scale—I. Item selection and cross-validation of the factor structure. J. Psychosom. Res. 38, 23–32. https://doi.org/10.1016/0022-3999(94)90005-1

Bakermans-Kranenburg, M.J., van IJzendoorn, M.H., Juffer, F., 2003. Less is more: Meta-analyses of sensitivity and attachment interventions in early childhood. Psychol. Bull. 129, 195–215. https://doi.org/10.1037/0033-2909.129.2.195

Beck, A.T., Steer, R.A., 1990. Manual for the Beck anxiety inventory. San Antonio, TX Psychol. Corp.

Beck, A.T., Steer, R.A., Ball, R., Ranieri, W.F., 1996. Comparison of Beck Depression Inventories-

IA and-II in Psychiatric Outpatients. J. Pers. Assess. 67, 588–597. https://doi.org/10.1207/s15327752jpa6703_13

Beck, A.T., Ward, C., Mendelson, M., 1961. Beck depression inventory (BDI). Arch Gen Psychiatry 4, 561–571.

Bernstein, R.E., Tenedios, C.M., Laurent, H.K., Measelle, J.R., Ablow, J.C., 2014. The eye of the begetter: predicting infant attachment disorganization from women's prenatal interpretations of infant facial expressions. Infant Ment. Health J. 35, 233–244. https://doi.org/10.1002/imhj.21438

Berry, D., Blair, C., Willoughby, M., Granger, D.A., Mills-Koonce, W.R., 2017. Maternal sensitivity and adrenocortical functioning across infancy and toddlerhood: Physiological adaptation to context? Dev. Psychopathol. 29, 303–317. https://doi.org/10.1017/S0954579416000158

Bick, J., Dozier, M., Bernard, K., Grasso, D., Simons, R., 2013. Foster Mother-Infant Bonding: Associations Between Foster Mothers' Oxytocin Production, Electrophysiological Brain Activity, Feelings of Commitment, and Caregiving Quality. Child Dev. 84, 826–840. https://doi.org/10.1111/cdev.12008

Bowlby, J., 1969. Attachment and loss, Vol. 1: Attachment. Basic Books, New York.

Bridges, R.S., Robertson, M.C., Shiu, R.P.C., Friesen, H.G., Stuer, A.M., Mann, P.E., 1996. Endocrine Communication between Conceptus and Mother: Placental Lactogen Stimulation of Maternal Behavior. Neuroendocrinology 64, 57–64. https://doi.org/10.1159/000127098

Briere, J., Runtz, M., 1989. The Trauma Symptom Checklist (TSC-33). J. Interpers. Violence 4, 151–163. https://doi.org/10.1177/088626089004002002

Brindle, P.M., Brown, M.W., Brown, J., Griffith, H.B., Turner, G.M., 1991. Objective and subjective memory impairment in pregnancy. Psychol. Med. 21, 647. https://doi.org/10.1017/S0033291700022285

Brockington, I.F., Fraser, C., Wilson, D., 2006. The Postpartum Bonding Questionnaire: a

validation. Arch. Womens. Ment. Health 9, 233–242. https://doi.org/10.1007/s00737-006-0132-1

Brunton, P.J., Russell, J.A., 2008. The expectant brain: adapting for motherhood. Nat. Rev. Neurosci. 9, 11–25. https://doi.org/10.1038/nrn2280

Brunton, R.J., Dryer, R., Saliba, A., Kohlhoff, J., 2015. Pregnancy anxiety: A systematic review of current scales. J. Affect. Disord. 176, 24–34. https://doi.org/10.1016/j.jad.2015.01.039

Cobey, K.D., Little, A.C., Roberts, S.C., 2015. Hormonal effects on women's facial masculinity preferences: The influence of pregnancy, post-partum, and hormonal contraceptive use. Biol. Psychol. 104, 35–40.

Cox, J.L., Holden, J.M., Sagovsky, R., 1987. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. Br. J. Psychiatry 150, 782–786. https://doi.org/10.1192/bjp.150.6.782

Crawley, R., Grant, S., Hinshaw, K., 2008. Cognitive changes in pregnancy: mild decline or societal stereotype? Appl. Cogn. Psychol. 22, 1142–1162. https://doi.org/10.1002/acp.1427

De Carli, P., Riem, M.M.E., Parolin, L., 2017. Approach-avoidance responses to infant facial expressions in nulliparous women: Associations with early experience and mood induction. Infant Behav. Dev. 49, 104–113. https://doi.org/10.1016/j.infbeh.2017.08.005

De Carli, P., Tagini, A., Sarracino, D., Santona, A., Bonalda, V., Cesari, P.E., Parolin, L., 2018. Like grandparents, like parents: Empirical evidence and psychoanalytic thinking on the transmission of parenting styles. Bull. Menninger Clin. 82, 46–70. https://doi.org/10.1521/bumc_2017_81_11

De Carli, P., Tagini, A., Sarracino, D., Santona, A., Parolin, L., 2016. Implicit Attitude Toward Caregiving: The Moderating Role of Adult Attachment Styles. Front. Psychol. 6. https://doi.org/10.3389/fpsyg.2015.01906

Deoliveira, C.A., Moran, G., Pederson, D.R., 2005. Understanding the link between maternal adult attachment classifications and thoughts and feelings about emotions. Attach. Hum. Dev. 7,

153–70. https://doi.org/10.1080/14616730500135032

Derntl, B., Windischberger, C., Robinson, S., Lamplmayr, E., Kryspin-Exner, I., Gur, R.C., Moser, E., Habel, U., 2008. Facial emotion recognition and amygdala activation are associated with menstrual cycle phase. Psychoneuroendocrinology 33, 1031–1040. https://doi.org/10.1016/j.psyneuen.2008.04.014

Donovan, W., Leavitt, L., Taylor, N., Broder, J., 2007. Maternal sensory sensitivity, mother–infant 9-month interaction, infant attachment status: Predictors of mother–toddler interaction at 24 months. Infant Behav. Dev. 30, 336–352. https://doi.org/10.1016/j.infbeh.2006.10.002

Dunkel Schetter, C., 2011. Psychological Science on Pregnancy: Stress Processes, Biopsychosocial Models, and Emerging Research Issues. Annu. Rev. Psychol. 62, 531–558. https://doi.org/10.1146/annurev.psych.031809.130727

Edelstein, R.S., Chopik, W.J., Saxbe, D.E., Wardecker, B.M., Moors, A.C., LaBelle, O.P., 2017. Prospective and dyadic associations between expectant parents' prenatal hormone changes and postpartum parenting outcomes. Dev. Psychobiol. 59, 77–90. https://doi.org/10.1002/dev.21469

Edwards, R.C., Hans, S.L., 2016. Prenatal Depressive Symptoms and Toddler Behavior Problems: The Role of Maternal Sensitivity and Child Sex. Child Psychiatry Hum. Dev. 47, 696–707. https://doi.org/10.1007/s10578-015-0603-6

Emde, R.N., Osofsky, J.D., Butterfield, P.M., 1987. The IFEEL pictures: A new instrument for interpreting emotions. International Universities Press, Inc, Madison.

Evans, K., Morrell, C.J., Spiby, H., 2017. Systematic review and meta-analysis of non-pharmacological interventions to reduce the symptoms of mild to moderate anxiety in pregnant women. J. Adv. Nurs. https://doi.org/10.1111/jan.13456

Field, T., Diego, M., Hernandez-Reif, M., Figueiredo, B., Deeds, O., Ascencio, A., Schanberg, S., Kuhn, C., 2010. Comorbid depression and anxiety effects on pregnancy and neonatal outcome. Infant Behav. Dev. 33, 23–29. https://doi.org/10.1016/j.infbeh.2009.10.004

Fleming, A.S., Corter, C., Franks, P., Surbey, M., Schneider, B., Steiner, M., 1993. Postpartum factors related to mother's attraction to newborn infant odors. Dev. Psychobiol. 26, 115–132. https://doi.org/10.1002/dev.420260204

Fleming, A.S., Korsmit, M., Deller, M., 1994. Rat pups are potent reinforcers to the maternal animal: Effects of experience, parity, hormones, and dopamine function. Psychobiology 22, 44–53.

Fleming, A.S., Luebke, C., 1981. Timidity prevents the virgin female rat from being a good mother: Emotionality differences between nulliparous and parturient females. Physiol. Behav. 27, 863–868. https://doi.org/10.1016/0031-9384(81)90054-8

Gavin, N.I., Gaynes, B.N., Lohr, K.N., Meltzer-Brody, S., Gartlehner, G., Swinson, T., 2005. Perinatal Depression: a systematic review of prevalence and incidence. Obstet. Gynecol. 106, 1071–1083. https://doi.org/10.1097/01.AOG.0000183597.31630.db

Gil, S., Teissèdre, F., Chambres, P., Droit-Volet, S., 2011. The evaluation of emotional facial expressions in early postpartum depression mood: A difference between adult and baby faces? Psychiatry Res. 186, 281–286. https://doi.org/10.1016/j.psychres.2010.06.015

Gingnell, M., Bannbers, E., Moes, H., Engman, J., Sylvén, S., Skalkidou, A., Kask, K., Wikström, J., Sundström-Poromaa, I., 2015. Emotion Reactivity Is Increased 4-6 Weeks Postpartum in Healthy Women: A Longitudinal fMRI Study. PLoS One 10, e0128964. https://doi.org/10.1371/journal.pone.0128964

Goldberg, L.R., Freyd, J.J., 2006. Self-Reports of Potentially Traumatic Experiences in an Adult Community Sample: Gender Differences and Test-Retest Stabilities of the Items in a Brief Betrayal-Trauma Survey. J. Trauma Dissociation 7, 39–63. https://doi.org/10.1300/J229v07n03_04

Grasso, D.J., Moser, J.S., Dozier, M., Simons, R., 2009. ERP correlates of attention allocation in mothers processing faces of their children. Biol. Psychol. 81, 95–102. https://doi.org/10.1016/j.biopsycho.2009.03.001

Guapo, V.G., Graeff, F.G., Zani, A.C.T., Labate, C.M., dos Reis, R.M., Del-Ben, C.M., 2009. Effects of sex hormonal levels and phases of the menstrual cycle in the processing of emotional faces. Psychoneuroendocrinology 34, 1087–1094. https://doi.org/10.1016/j.psyneuen.2009.02.007

Hariri, A.R., Mattay, V.S., Tessitore, A., Fera, F., Weinberger, D.R., 2003. Neocortical modulation of the amygdala response to fearful stimuli. Biol. Psychiatry 53, 494–501. https://doi.org/10.1016/S0006-3223(02)01786-9

Haxby, J. V., Hoffman, E.A., Gobbini, M.I., 2002. Human neural systems for face recognition and social communication. Biol. Psychiatry 51, 59–67. https://doi.org/10.1016/S0006-3223(01)01330-0

Henry, J.D., Rendell, P.G., 2007. A review of the impact of pregnancy on memory function. J. Clin. Exp. Neuropsychol. 29, 793–803. https://doi.org/10.1080/13803390701612209

Hoekzema, E., Barba-Müller, E., Pozzobon, C., Picado, M., Lucco, F., García-García, D., Soliva, J.C., Tobeña, A., Desco, M., Crone, E.A., Ballesteros, A., Carmona, S., Vilarroya, O., 2016. Pregnancy leads to long-lasting changes in human brain structure. Nat. Neurosci. 20, 287–296. https://doi.org/10.1038/nn.4458

Jones, B.C., Perrett, D.I., Little, A.C., Boothroyd, L., Cornwell, R.E., Feinberg, D.R., Tiddeman, B.P., Whiten, S., Pitman, R.M., Hillier, S.G., Burt, D.M., Stirrat, M.R., Law Smith, M.J., Moore, F.R., 2005. Menstrual cycle, pregnancy and oral contraceptive use alter attraction to apparent health in faces. Proc. R. Soc. B Biol. Sci. 272, 347–354. https://doi.org/10.1098/rspb.2004.2962

Joormann, J., Gotlib, I.H., 2006. Is this happiness I see? Biases in the identification of emotional facial expressions in depression and social phobia. J. Abnorm. Psychol. 115, 705–714. https://doi.org/10.1037/0021-843X.115.4.705

Kapoor, A., Dunn, E., Kostaki, A., Andrews, M.H., Matthews, S.G., 2006. Fetal programming of hypothalamo-pituitary-adrenal function: prenatal stress and glucocorticoids. J. Physiol. 572,

31–44. https://doi.org/10.1113/jphysiol.2006.105254

Kessler, R.C., Barker, P.R., Colpe, L.J., Epstein, J.F., Gfroerer, J.C., Hiripi, E., Howes, M.J., Normand, S.-L.T., Manderscheid, R.W., Walters, E.E., Zaslavsky, A.M., 2003. Screening for Serious Mental Illness in the General Population. Arch. Gen. Psychiatry 60, 184. https://doi.org/10.1001/archpsyc.60.2.184

Kinsley, C.H., Bales, K.L., Bardi, M., Stolzenberg, D.S., 2015. Reproductive experiential regulation of cognitive and emotional resilience. Neurosci. Biobehav. Rev. 58, 92–106. https://doi.org/10.1016/j.neubiorev.2015.05.015

Kinsley, C.H., Madonia, L., Gifford, G.W., Tureski, K., Griffin, G.R., Lowry, C., Williams, J., Collins, J., McLearie, H., Lambert, K.G., 1999. Motherhood improves learning and memory. Nature 401, 137–138. https://doi.org/10.1038/45957

Kringelbach, M.L., Stark, E.A., Alexander, C., Bornstein, M.H., Stein, A., 2016. On Cuteness: Unlocking the Parental Brain and Beyond. Trends Cogn. Sci. 20, 545–558. https://doi.org/10.1016/j.tics.2016.05.003

Lee, A.M., Lam, S.K., Sze Mun Lau, S.M., Chong, C.S.Y., Chui, H.W., Fong, D.Y.T., 2007. Prevalence, Course, and Risk Factors for Antenatal Anxiety and Depression. Obstet. Gynecol. 110, 1102–1112. https://doi.org/10.1097/01.AOG.0000287065.59491.70

Leerkes, E.M., 2011. Maternal sensitivity during distressing tasks: A unique predictor of attachment security. Infant Behav. Dev. 34, 443–446. https://doi.org/10.1016/j.infbeh.2011.04.006

Leerkes, E.M., 2010. Predictors of Maternal Sensitivity to Infant Distress. Parent. Sci. Pract. 10, 219–239. https://doi.org/10.1080/15295190903290840

Leerkes, E.M., Supple, A.J., O'Brien, M., Calkins, S.D., Haltigan, J.D., Wong, M.S., Fortuna, K., 2014. Antecedents of Maternal Sensitivity During Distressing Tasks: Integrating Attachment, Social Information Processing, and Psychobiological Perspectives. Child Dev. https://doi.org/10.1111/cdev.12288

Lehmann, V., Huis in't Veld, E.M.J., Vingerhoets, A.J.J.M., 2013. The human and animal baby

schema effect: Correlates of individual differences. Behav. Processes 94, 99–108. https://doi.org/10.1016/j.beproc.2013.01.001

LeMoult, J., Joormann, J., 2012. Attention and Memory Biases in Social Anxiety Disorder: The Role of Comorbid Depression. Cognit. Ther. Res. 36, 47–57. https://doi.org/10.1007/s10608-010-9322-2

Letourneau, N.L., Dennis, C.-L., Cosic, N., Linder, J., 2017a. The effect of perinatal depression treatment for mothers on parenting and child development: A systematic review. Depress. Anxiety 34, 928–966. https://doi.org/10.1002/da.22687

Letourneau, N.L., Dennis, C.-L., Cosic, N., Linder, J., 2017b. The effect of perinatal depression treatment for mothers on parenting and child development: A systematic review. Depress. Anxiety 34, 928–966. https://doi.org/10.1002/da.22687

Lewis, G., Pelosi, A.J., Araya, R., Dunn, G., 1992. Measuring psychiatric disorder in the community: a standardized assessment for use by lay interviewers. Psychol. Med. 22, 465. https://doi.org/10.1017/S0033291700030415

Macbeth, A.H., Luine, V.N., 2010. Changes in anxiety and cognition due to reproductive experience: A review of data from rodent and human mothers. Neurosci. Biobehav. Rev. 34, 452–467. https://doi.org/10.1016/j.neubiorev.2009.08.011

Macrae, J.A., Pearson, R.M., Lee, R., Chauhan, D., Bennert, K., Burns, A., Baxter, H., Evans, J., 2015. The impact of depression on maternal responses to infant faces in pregnancy. Infant Ment. Health J. 36, 588–598. https://doi.org/10.1002/imhj.21538

Malak, S.M., Crowley, M.J., Mayes, L.C., Rutherford, H.J.V., 2015. Maternal anxiety and neural responses to infant faces. J. Affect. Disord. 172, 324–330. https://doi.org/10.1016/j.jad.2014.10.013

Marsh, A.A., Yu, H.H., Pine, D.S., Gorodetsky, E.K., Goldman, D., Blair, R.J.R., 2012. The influence of oxytocin administration on responses to infant faces and potential moderation by OXTR genotype. Psychopharmacology (Berl). 224, 469–476. https://doi.org/10.1007/s00213-

012-2775-0

Milgrom, J., Holt, C.C.J., Holt, C.C.J., Ross, J., Ericksen, J., Gemmill, A.W., 2015. Feasibility study and pilot randomised trial of an antenatal depression treatment with infant follow-up. Arch. Womens. Ment. Health 18, 717–730. https://doi.org/10.1007/s00737-015-0512-5

Montgomery, S.A., Asberg, M., 1979. A new depression scale designed to be sensitive to change. Br. J. Psychiatry 134, 382–389. https://doi.org/10.1192/bjp.134.4.382

Montirosso, R., Arrigoni, F., Casini, E., Nordio, A., De Carli, P., Di Salle, F., Moriconi, S., Re, M., Reni, G., Borgatti, R., 2017. Greater brain response to emotional expressions of their own children in mothers of preterm infants: an fMRI study. J. Perinatol. https://doi.org/10.1038/jp.2017.2

Moser, J.S., Huppert, J.D., Duval, E., Simons, R.F., 2008. Face processing biases in social anxiety: An electrophysiological study. Biol. Psychol. 78, 93–103. https://doi.org/10.1016/j.biopsycho.2008.01.005

Murphy, S.E., Braithwaite, E.C., Hubbard, I., Williams, K. V., Tindall, E., Holmes, E.A., Ramchandani, P.G., 2015. Salivary cortisol response to infant distress in pregnant women with depressive symptoms. Arch. Womens. Ment. Health 18, 247–253. https://doi.org/10.1007/s00737-014-0473-0

Murray, D., Cox, J.L., 1990. Screening for depression during pregnancy with the edinburgh depression scale (EDDS). J. Reprod. Infant Psychol. 8, 99–107. https://doi.org/10.1080/02646839008403615

Musser, E.D., Kaiser-Laurent, H., Ablow, J.C., 2012. The neural correlates of maternal sensitivity: an fMRI study. Dev. Cogn. Neurosci. 2, 428–436. https://doi.org/10.1016/j.dcn.2012.04.003

Netsi, E., Evans, J., Wulff, K., O'Mahen, H., Ramchandani, P.G., 2015. Infant outcomes following treatment of antenatal depression: Findings from a pilot randomized controlled trial. J. Affect. Disord. 188, 252–256. https://doi.org/10.1016/j.jad.2015.08.055

Numan, M., 2007. Motivational systems and the neural circuitry of maternal behavior in the rat.

Dev. Psychobiol. 49, 12–21. https://doi.org/10.1002/dev.20198

O'Connor, T.G., Heron, J., Glover, V., 2002. Antenatal Anxiety Predicts Child Behavioral/Emotional Problems Independently of Postnatal Depression. J. Am. Acad. Child Adolesc. Psychiatry 41, 1470–1477. https://doi.org/10.1097/00004583-200212000-00019

O'Donnell, K., O'Connor, T.G., Glover, V., 2009. Prenatal Stress and Neurodevelopment of the Child: Focus on the HPA Axis and Role of the Placenta. Dev. Neurosci. 31, 285–292. https://doi.org/10.1159/000216539

Oldfield, R.C., 1971. The assessment and analysis of handedness: The Edinburgh inventory. Neuropsychologia 9, 97–113. https://doi.org/10.1016/0028-3932(71)90067-4

Oliveira, V., Goulart, M., Nobre, J.C., Lucion, M.K., Silveira, P.P., Bizarro, L., 2017. Emotional interference of baby and adult faces on automatic attention in parenthood. Psychol. Neurosci. 10, 144–153. https://doi.org/10.1037/pne0000085

Parsons, C.E., Young, K.S., Petersen, M. V., Jegindoe Elmholdt, E.-M., Vuust, P., Stein, A., Kringelbach, M.L., 2017. Duration of motherhood has incremental effects on mothers' neural processing of infant vocal cues: a neuroimaging study of women. Sci. Rep. 7, 1727. https://doi.org/10.1038/s41598-017-01776-3

Paschetta, E., Berrisford, G., Coccia, F., Whitmore, J., Wood, A.G., Pretlove, S., Ismail, K.M.K., 2014. Perinatal psychiatric disorders: an overview. Am. J. Obstet. Gynecol. 210, 501–509.e6. https://doi.org/10.1016/j.ajog.2013.10.009

Pearson, R.M., Cooper, R.M., Penton-Voak, I.S., Lightman, S.L., Evans, J., 2010. Depressive symptoms in early pregnancy disrupt attentional processing of infant emotion. Psychol. Med. 40, 621. https://doi.org/10.1017/S0033291709990961

Pearson, R.M., Evans, J., Kounali, D., Lewis, G., Heron, J., Ramchandani, P.G., O'Connor, T.G., Stein, A., 2013a. Maternal Depression During Pregnancy and the Postnatal Period. JAMA Psychiatry 70, 1312. https://doi.org/10.1001/jamapsychiatry.2013.2163

Pearson, R.M., Lightman, S.L., Evans, J., 2012a. Symptoms of depression during pregnancy are

associated with increased systolic blood pressure responses towards infant distress. Arch. Womens. Ment. Health 15, 95–105. https://doi.org/10.1007/s00737-012-0269-z

Pearson, R.M., Lightman, S.L., Evans, J., 2011. Attentional processing of infant emotion during late pregnancy and mother–infant relations after birth. Arch. Womens. Ment. Health 14, 23–31. https://doi.org/10.1007/s00737-010-0180-4

Pearson, R.M., Lightman, S.L., Evans, J., 2009. Emotional sensitivity for motherhood: Late pregnancy is associated with enhanced accuracy to encode emotional faces. Horm. Behav. 56, 557–563. https://doi.org/10.1016/j.yhbeh.2009.09.013

Pearson, R.M., Melotti, R., Heron, J., Joinson, C., Stein, A., Ramchandani, P.G., Evans, J., 2012b. Disruption to the development of maternal responsiveness? The impact of prenatal depression on mother–infant interactions. Infant Behav. Dev. 35, 613–626. https://doi.org/10.1016/j.infbeh.2012.07.020

Pearson, R.M., O'Mahen, H., Burns, A., Bennert, K., Shepherd, C., Baxter, H., Chauhan, D., Evans, J., 2013b. The normalisation of disrupted attentional processing of infant distress in depressed pregnant women following Cognitive Behavioural Therapy. J. Affect. Disord. 145, 208–213. https://doi.org/10.1016/j.jad.2012.07.033

Peltola, M.J., Yrttiaho, S., Puura, K., Proverbio, A.M., Mononen, N., Lehtimäki, T., Leppänen, J.M., 2014. Motherhood and oxytocin receptor genetic variation are associated with selective changes in electrocortical responses to infant facial expressions. Emotion 14, 469–477. https://doi.org/10.1037/a0035959

Pollack, M.H., 2005. Comorbid anxiety and depression. J. Clin. Psychiatry 66 Suppl 8, 22–9.

Proverbio, A.M., Brignone, V., Matarazzo, S., Del Zotto, M., Zani, A., 2006. Gender and parental status affect the visual cortical response to infant facial expression. Neuropsychologia 44, 2987–2999. https://doi.org/10.1016/j.neuropsychologia.2006.06.015

Raby, K.L., Roisman, G.I., Fraley, R.C., Simpson, J.A., 2015. The Enduring Predictive Significance of Early Maternal Sensitivity: Social and Academic Competence Through Age 32 Years. Child

Dev. 86, 695–708. https://doi.org/10.1111/cdev.12325

Radloff, L.S., 1977. The CES-D Scale. Appl. Psychol. Meas. 1, 385–401. https://doi.org/10.1177/014662167700100306

Rayson, H., Bonaiuto, J.J., Ferrari, P.F., Murray, L., 2017. Early maternal mirroring predicts infant motor system activation during facial expression observation. Sci. Rep. 7, 11738. https://doi.org/10.1038/s41598-017-12097-w

Raz, S., 2014. Behavioral and neural correlates of cognitive–affective function during late pregnancy: An Event-Related Potentials Study. Behav. Brain Res. 267, 17–25. https://doi.org/10.1016/j.bbr.2014.03.021

Riem, M.M.E., Bakermans-Kranenburg, M.J., Voorthuis, A., van IJzendoorn, M.H., 2014. Oxytocin effects on mind-reading are moderated by experiences of maternal love withdrawal: an fMRI study. Prog. Neuropsychopharmacol. Biol. Psychiatry 51, 105–12. https://doi.org/10.1016/j.pnpbp.2014.01.014

Riem, M.M.E., De Carli, P., van IJzendoorn, M.H.M.H., Linting, M., Grewen, K.M.K.M., Bakermans-Kranenburg, M.J.M.J., IJzendoorn, M.H. van, Linting, M., Grewen, K.M.K.M., Bakermans-Kranenburg, M.J.M.J., De Carli, P., van IJzendoorn, M.H.M.H., Linting, M., Grewen, K.M.K.M., Bakermans-Kranenburg, M.J.M.J., 2017a. Emotional maltreatment is associated with atypical responding to stimulation of endogenous oxytocin release through mechanically-delivered massage in males. Psychoneuroendocrinology 85. https://doi.org/10.1016/j.psyneuen.2017.08.017

Riem, M.M.E., van IJzendoorn, M.H., De Carli, P., Vingerhoets, A.J.J.M., Bakermans-Kranenburg, M.J., 2017b. As tears go by: Baby tears trigger more brain activity than adult tears in nulliparous women. Soc. Neurosci. 1–4. https://doi.org/10.1080/17470919.2016.1247012

Riem, M.M.E., van IJzendoorn, M.H., De Carli, P., Vingerhoets, A.J.J.M., Bakermans-Kranenburg, M.J., 2017c. Behavioral and neural responses to infant and adult tears: The impact of maternal love withdrawal. Emotion 17, 1021–1029. https://doi.org/10.1037/emo0000288

Roos, A., Lochner, C., Kidd, M., van Honk, J., Vythilingum, B., Stein, D.J., 2012. Selective attention to fearful faces during pregnancy. Prog. Neuro-Psychopharmacology Biol. Psychiatry 37, 76–80. https://doi.org/10.1016/j.pnpbp.2011.11.012

Roos, A., Robertson, F., Lochner, C., Vythilingum, B., Stein, D.J., 2011. Altered prefrontal cortical function during processing of fear-relevant stimuli in pregnancy. Behav. Brain Res. 222, 200–205. https://doi.org/10.1016/j.bbr.2011.03.055

Rutherford, H.J.V., Byrne, S.P., Austin, G.M., Lee, J.D., Crowley, M.J., Mayes, L.C., 2017. Anxiety and neural responses to infant and adult faces during pregnancy. Biol. Psychol. 125, 115–120. https://doi.org/10.1016/j.biopsycho.2017.03.002

Rutherford, H.J.V., Graber, K.M., Mayes, L.C., 2016. Depression symptomatology and the neural correlates of infant face and cry perception during pregnancy. Soc. Neurosci. 11, 467–474. https://doi.org/10.1080/17470919.2015.1108224

Sacchi, C., De Carli, P., Vieno, A., Piallini, G., Zoia, S., Simonelli, A., 2018. Does infant negative emotionality moderate the effect of maternal depression on motor development? Early Hum. Dev. 119, 56–61. https://doi.org/10.1016/j.earlhumdev.2018.03.006

Schurz, M., Radua, J., Aichhorn, M., Richlan, F., Perner, J., 2014. Fractionating theory of mind: A meta-analysis of functional brain imaging studies. Neurosci. Biobehav. Rev. 42, 9–34. https://doi.org/10.1016/j.neubiorev.2014.01.009

Schutter, D.J.L.G., Hofman, D., Van Honk, J., 2008. Fearful faces selectively increase corticospinal motor tract excitability: A transcranial magnetic stimulation study. Psychophysiology 45, 345–348. https://doi.org/10.1111/j.1469-8986.2007.00635.x

Seifritz, E., Esposito, F., Neuhoff, J.G., Lüthi, A., Mustovic, H., Dammann, G., von Bardeleben, U., Radue, E.W., Cirillo, S., Tedeschi, G., Di Salle, F., 2003. Differential sex-independent amygdala response to infant crying and laughing in parents versus nonparents. Biol. Psychiatry 54, 1367–1375. https://doi.org/10.1016/S0006-3223(03)00697-8

Shamay-Tsoory, S.G., Abu-Akel, A., 2015. The social salience hypothesis of oxytocin. Biol.

Psychiatry. https://doi.org/10.1016/j.biopsych.2015.07.020

Shin, L.M., Liberzon, I., 2010. The Neurocircuitry of Fear, Stress, and Anxiety Disorders. Neuropsychopharmacology 35, 169–191. https://doi.org/10.1038/npp.2009.83

Skuse, D.H., 2005. Measuring autistic traits: heritability, reliability and validity of the Social and Communication Disorders Checklist. Br. J. Psychiatry 187, 568–572. https://doi.org/10.1192/bjp.187.6.568

Spielberger, C.D., 1985. Assessment of state and trait anxiety: Conceptual and methodological issues. South. Psychol. 2, 6–16.

Stallings, J., Fleming, A.S., Corter, C., Worthman, C., Steiner, M., 2001. The Effects of Infant Cries and Odors on Sympathy, Cortisol, and Autonomic Responses in New Mothers and Nonpostpartum Women. Parenting 1, 71–100. https://doi.org/10.1080/15295192.2001.9681212

Stein, A., Arteche, A., Lehtonen, A., Craske, M., Harvey, A., Counsell, N., Murray, L., 2010. Interpretation of infant facial expression in the context of maternal postnatal depression. Infant Behav. Dev. 33, 273–278. https://doi.org/10.1016/j.infbeh.2010.03.002

Stein, A., Pearson, R.M., Goodman, S.H., Rapa, E., Rahman, A., McCallum, M., Howard, L.M., Pariante, C.M., 2014. Effects of perinatal mental disorders on the fetus and child. Lancet 384, 1800–1819. https://doi.org/10.1016/S0140-6736(14)61277-0

Stewart, D.E., 2011. Depression during Pregnancy. N. Engl. J. Med. 365, 1605–1611. https://doi.org/10.1056/NEJMcp1102730

Sundström Poromaa, I., Gingnell, M., 2014. Menstrual cycle influence on cognitive function and emotion processing-"from a reproductive perspective. Front. Neurosci. 8. https://doi.org/10.3389/fnins.2014.00380

Thompson-Booth, C., Viding, E., Mayes, L.C., Rutherford, H.J.V., Hodsoll, S., McCrory, E.J., 2014. Here's looking at you, kid: attention to infant emotional faces in mothers and non-mothers. Dev. Sci. 17, 35–46. https://doi.org/10.1111/desc.12090

Watson, D., Clark, L.A., Tellegen, A., 1988. Development and validation of brief measures of positive and negative affect: The PANAS scales. J. Pers. Soc. Psychol. 54, 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Wechsler, D., 1997. WMS-III: Wechsler memory scale administration and scoring manual. Psychological Corporation.

World Health Organization, 1992. The ICD-10 classification of mental and behavioural disorders: clinical descriptions and diagnostic guidelines. World Health Organization.

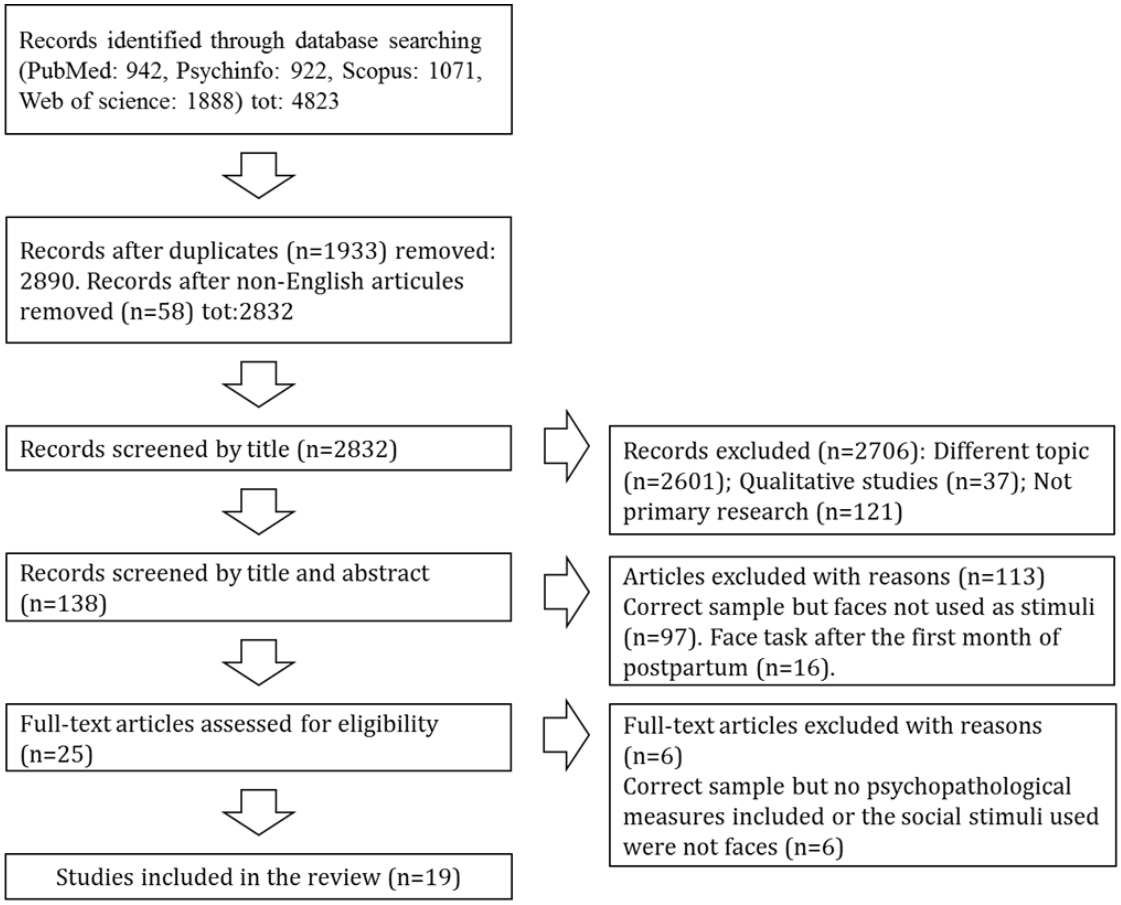

Figure 1. Flow Chart: Process of systematic search for literature